International Journal of Innovative Technology and Creative Engineering - IJITCE (ISSN:2045-8711)Vol.15 No.04 Apr 2025

IJITCE PUBLICATION

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IJITCE PUBLICATION

International Journal of Innovative Technology and Creative Engineering

IJITCE (ISSN:2045-8711)

Vol.15 No.04 Apr 2025

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From The Editorial Board

Dear Researcher,
Greetings!

Articles in this issue discusses about

1. Artificial Reef Deployment with Community Participation
2. Reef for Fish Forever - Article
3. Sea Survey Study to deploy artificial reefs at the off coast of Palk Bay
4. Sustaining India's Coastal and Marine Ecosystems Challenges, Strategies, and Pathways to Resilience. A Study.
5. Enrichment of Traditional Chutney Powder Using Anchovies
6. AI Powered Mitigating techniques to Protect and detect illegal trafficking of flora and fauna of marine endangered species in the digital era

We look forward many more new technologies in the next month.

Thanks,
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Editorial Board

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International Journal of Innovative Technology and Creative Engineering - IJITCE (ISSN:2045-8711) Vol.15 No.04 Apr 2025

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Artificial Reef Deployment with Community Participation: A Pathway to Sustainable Livelihoods and Socio-Economic Upliftment of Traditional Fishers – A Study

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ABSTRACT

This paper explores various methods employed and experiences gained in the fabrication, deployment, and monitoring of artificial reefs along the east coast of Tamil Nadu by governmental and non-governmental organizations. The community participatory method has proven to be the most effective in yielding positive outcomes for both the fishing community and the environment. This approach enhances biodiversity, ensures better livelihoods, and promotes biological resource enrichment, particularly in fishery resources. The involvement of fisher communities along the Tamil Nadu coast in the establishment and utilization of artificial reefs is discussed. It is strongly recommended that community participation be ensured to achieve optimal results in artificial reef projects.

1. Introduction

Food security and nutritional standards are two key priorities emphasized in the developmental plans of most developing countries. The current agricultural land is insufficient to meet the growing food demand due to constraints on cultivable land for crops, cattle, and poultry. As a result, we must increasingly rely on marine resources, as the ocean's production potential is three-dimensional and can be significantly enhanced through conservation, resource management, and mariculture.

The biological productivity in coastal waters is twelve times higher than that of deep-sea waters due to sunlight penetration, which promotes primary production. This, in turn, triggers better secondary and tertiary production, particularly in fishery resources. Hence, nearshore waters serve as breeding, feeding, and nursery grounds for numerous species, leading to high species abundance and diversity.

India's marine fish production has increased from a mere 0.38 million tonnes in 1950 to 3.2 million tonnes in 2008, but it has stagnated at around 3 million tonnes in recent years due to overfishing in inshore waters. The estimated potential yield of 2.2 million tonnes from inshore waters has already been reached, with nearly 90% of fishing efforts concentrated in these zones.

Additionally, inshore waters face severe degradation due to developmental activities, pollution, intensive bottom trawling, and unsustainable fishing practices. The absence of proper management and conservation measures has led to the depletion of fish stocks, posing a risk to food security. To address this, efforts have been made to improve indigenous artificial reef technology, known as "Mullam," by enhancing its durability and ecosystem services. This adaptation serves not only as a biodiversity enhancement tool but also as a means to improve the socio-economic conditions of traditional coastal fishers. One such initiative by the PLANT Trust is the deployment of artificial reefs to restore coastal ecosystems, increase biodiversity, and enhance fishery resources through community participation.

2. Traditional Artificial Reefs and Indigenous Knowledge (ITK)

Traditionally, artificial reefs were designed to attract and concentrate fish at specific locations for seasonal harvesting. Fishers used entire trees or bundled branches weighted with stones as anchors in shallow

waters, attracting fish due to the biodegradation of leaves and bark. However, these reefs were temporary and often displaced by mechanized bottom trawlers, necessitating costly seasonal reconstruction.

3. Modern Artificial Reef Concept

Modern artificial reefs are constructed using reinforced concrete in various shapes to accommodate different fish species. These structures increase the availability of hard substrata on the seafloor, promoting the settlement of benthic flora and fauna. The resulting ecosystem provides food, shelter, and breeding grounds for fish, enhancing population growth and ensuring a sustainable fishery for artisanal fishers.

4. Institution Building

To ensure long-term sustainability, selected fishing villages are introduced to artificial reef technology through video presentations and workshops. Fishers are encouraged to form and register an "Artificial Reef Fabrication, Deployment & Monitoring Committee" under the Societies Act. This committee, comprising expert fishers and community leaders, serves as the governing body for reef establishment and utilization.

5. Community Participation and Ownership

After forming the expert committee, a Memorandum of Understanding (MoU) is signed, designating the artificial reef as village property. The committee assumes responsibility for fabrication, deployment, and monitoring, with technical and financial support provided by various funding agencies such as Ministry of Forest and Environment and Climate Change, Government of India, UNDP, GEF, SGP, Madras Atomic Power Station CSR project fund and Consulate General of Australia, Chennai through an implementing agency, the NGO Participatory Learning Action Network and Training Trust (PLANT).

Reef structures are fabricated on the village beach with active fisher participation. A technical team, including SCUBA divers and technology experts, identifies the most suitable deployment sites. Once completed, the structures are deployed on an auspicious day and monitored for six months before being opened for fishing, restricted to hook-and-line and gillnets. To date, PLANT has successfully implemented artificial reef projects in Thirty Six fishing villages and deployed more than 7200 reefs which created fish habitat across Tamil Nadu.

6. Empowering Traditional Fishers

Fishers gain comprehensive knowledge of modern artificial reefs, including fabrication, site selection, deployment, and sustainable fishing practices. This self-sufficiency allows them to construct and manage artificial reefs independently and share their expertise with neighboring fishing communities.

7. Monitoring and Accounting

Once fishing begins, the village committee monitors activities and records catches before marketing them. Revenue is collected, with a small percentage deducted for administrative expenses. These data are crucial for evaluating the economic viability of artificial reefs.

8. Economic Benefits of Artificial Reefs

Data from an artificial reef deployed in Kalpakkam in between 2012 to 2023 in 17 sites revealed that:

- Gillnet units landed an average annual catch of 136.2 tonnes, valued at ₹2.4 Crores and-line fishing, demonstrating significantly higher profitability for hook-and-line fishing.
- The payback period was calculated between 1 to 2 years for each site, making artificial reefs a highly viable investment for fishermen.

9. Ecological Benefits

Artificial reefs introduce structural complexity to barren environments, increasing surface area for benthic organisms. This promotes species diversity and enhances primary production. The study estimated a 23-fold increase in substratum surface area after reef deployment, leading to rapid colonization by marine life such as barnacles, corals, algae, cuttlefish, crabs, and lobsters. These reefs also function as breeding and nursery grounds, supporting marine biodiversity.

10. Social Benefits

Artificial reefs function as community-owned assets, enabling equitable resource sharing among village fishers. They also deter mechanized trawlers from operating in shallow waters, reducing conflicts between traditional and mechanized fishers.

11. Conclusion: Impacts of Artificial Reefs

The deployment of artificial reefs yields multiple ecological, economic, and social benefits, including:

- Enhancement of marine biodiversity through increased habitat complexity.
- Restoration of coastal ecosystems and fishery resources.
- Empowerment of fishermen through participatory institution-building and training.
- Establishment of sustainable fishing practices, improving catch quality and value.
- Reduction in fuel consumption and carbon emissions due to shorter fishing trips.
- Strengthening of fishing communities through cooperative ownership and resource management.
- Regulation of illegal and destructive fishing practices to ensure sustainable resource utilization.

The findings highlight the immense potential of artificial reefs as a low-cost, eco-friendly technology to support marine conservation, fishery resource management, and socio-economic upliftment of traditional fishers in India. Expanding this initiative can lead to widespread benefits for coastal communities and the environment.

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Reef for Fish Forever
Deployment of Artificial Reefs to Enhance Marine Fisheries Resources for the Sustainable Livelihood Development of Fisherfolk at Kalpakkam, Chenglepet District in Tamil Nadu, India.

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Abstract

Enhancing Marine Biodiversity and Livelihoods through Artificial Reefs: A Case Study from Tamil Nadu

Artificial reefs have emerged as a sustainable solution for marine biodiversity conservation and fisheries enhancement along the Tamil Nadu coast. This project successfully deployed 200 artificial reef structures across a 1,000 sq. m core area, leading to significant ecological and socio-economic benefits. The reefs provide habitats for marine species, increasing fish biomass by 3,000 to 5,000 kg per month and benefiting over 1,200 fishing families directly and indirectly.

The initiative has contributed to reducing fishing pressure, lowering fuel consumption, and mitigating CO2 emissions. By eliminating long-distance fishing, the project has led to an estimated daily greenhouse gas reduction of 10.5 metric tons and fuel cost savings of Rs. 37,500 per day. These efforts have bolstered sustainable fishing practices, providing fishers with a stable income of Rs. 15,000 to Rs.20,000 per month per family. Additionally, the reefs act as natural wave breakers, helping to mitigate coastal erosion and improve coastal resilience.

To ensure long-term sustainability, a reef management program is proposed, including scuba diving training for local youth to clean entangled nets and promote ecotourism. The PLANT organization is spearheading efforts to scale up this model with support from the Madras Atomic Power Station (MAPS) and Tamil Nadu Fisheries Department. Recognizing its success, the Government of India, MoEF&CC, and UNDP have integrated artificial reef deployment into national fisheries policy, with Tamil Nadu allocating Rs. 10 crores for further expansion.

This project serves as a replicable model for coastal biodiversity conservation and fisheries sustainability, offering valuable lessons for national and global artificial reef initiatives.

Keywords: Artificial reefs, marine biodiversity, sustainable fisheries, coastal conservation, livelihood

enhancement, Tamil Nadu. VMC- Village Monitoring Committee, Coral Reefs,

1. Introduction

1.1. Project Concept and Detailed Description

Tamil Nadu, located at the southeastern tip of the Indian Peninsula, is one of India's oldest maritime states. Its coastline accounts for approximately 15% of the country's total coastal length, playing a crucial role in the national economy due to its rich biodiversity and productive marine habitats. However, unsustainable and unregulated fishing, coupled with extensive agricultural and industrial activities along the coast, has placed immense pressure on coastal ecosystems. Additionally, rapid urbanization and frequent natural disasters have further exacerbated the degradation of these regions, leading to a significant decline in fish productivity, aquatic biodiversity, and the livelihoods of local fishing communities.

Artificial reefs—man-made concrete structures placed on the seabed—serve as a crucial intervention to restore marine biodiversity. These structures increase the surface area available for marine organisms, offering shelter for fish and lobsters to feed and breed. The project includes the deployment of three different reef modules:

1. **Ring Ornamental Fish Module**
2. **Ferro Concrete Triangle Reef Fish Module (Somosa Module)**
3. **Triangular Grouper Module**

In response to these challenges, the Participatory Learning Action Network and Training (PLANT), a non-governmental organization dedicated to the socio-economic advancement of Tamil Nadu's fishing communities, initiated a coastal ecosystem restoration program in 2004. By integrating modern scientific methods with traditional knowledge, the organization developed artificial reefs, evolving from conventional fish aggregation structures known as *Mullam*—historically created using tree branches or tires. These artificial reefs, also known as Fish Aggregation Devices (FADs), have been deployed across areas ranging from 1,000 to 5,000 square meters near 17 marine fishing villages in Kalpakkam and Mahabalipuram region. The initiative has been supported through corporate social responsibility (CSR) funding from NPCIL-MAPS, Kalpakkam (formerly in Kancheepuram district, now in Chengalpattu district).

This project, implemented with the support of the Village Monitoring Committee (VMC), promotes sustainable fishing practices by banning destructive fishing gear and regulating fishing activities. Over the years, these efforts have resulted in a significant increase in aquatic biodiversity and fish populations, leading to enhanced fish production and improved socio-economic conditions for the fishing communities.

1.2. Bio-geographical Significance

Tamil Nadu is the only state in India where both the Western and Eastern Ghats converge at the Nilgiri Hills. Biogeographically a part of the Deccan Peninsula, the state has a coastline of approximately 1,076 km, bordered by the Indian Ocean to the south and the Bay of Bengal to the east. Tamil Nadu is endowed with a diverse range of coastal and marine ecosystems, including mangroves, coral reefs, seagrass beds, sand dunes, beaches, mudflats, salt marshes, wetlands, estuaries, and extensive marine waters. Notably, it is home to India's first Marine Biosphere Reserve, the Gulf of Mannar Biosphere Reserve (GOMBR).

The coastal ecosystem of Chenglepet district provides a range of vital ecological services, including food supply, water resources, livelihoods, coastal protection, and carbon sequestration.[1] The region's aquatic fauna includes commercially valuable crustaceans and finfish, as well as ecologically significant species such as Olive Ridley turtles, otters, shrimps, resident and migratory birds, and several threatened marine species. Among these are the Milk Shark (*Rhizoprionodon acutus*), Seer Fish (*Scomberomorus commerson*), Sea Cucumber, and Sea Horse. *(Specific information on the aquatic biodiversity of Cuddalore district and the project areas should be verified and incorporated accordingly.)*

1.3. Need for the Initiative

By the 1990s, a significant decline in fish populations along the Tamil Nadu coast was observed. This decline was attributed to both environmental and human-induced factors. Erratic rainfall patterns, the closure of river mouths, and natural disasters, coupled with industrial and developmental activities leading to the discharge of pollutants into coastal waters, severely impacted marine ecosystems.

However, the most pressing threat to the coastal environment was the overexploitation of marine resources due to unregulated and unsustainable fishing practices. The use of non-selective fishing gear, such as trawlers,[2] caused extensive damage to coral

[1] http://www.indiaenvironmentportal.org.in/files/file/soer2.pdf

[2] *Trawling is a method of fishing that involves pulling fishing net through the water behind one or more boats. The net that is used for trawling is called a trawl. The boats that are used for trawling are called trawlers or draggers.*

reefs, sharks, sea turtles, and other vulnerable marine species, including the Milk Shark, Seer Fish, Sea Cucumber, False Trevally (*Lactarius lactarius*), and Sea Horse.

Following the 2004 tsunami,[3] a voluntary organization distributed numerous fiber-reinforced plastic (FRP) boats and fishing nets to support the livelihoods of the affected fishing communities.[4] However, this inadvertently contributed to increased juvenile fish harvesting, further depleting aquatic populations and leaving little opportunity for marine species to breed and regenerate.

2. Genesis of the Initiative, Its Objective, and Governance

Recognizing the ecological decline in the region, PLANT launched an initiative to restore the coastal ecosystem by deploying artificial reefs across 1,000 square kilometers along the Chenglepet district coastline near the fishing hamlet of Pudupattinam, while also implementing measures to curb unsustainable fishing practices.

The primary objectives of the initiative were to:

- Increase the biological population and diversity of inshore waters,
- Enhance the population of threatened species dependent on small fish stocks, and
- Improve livelihood opportunities for local fishing communities.

To ensure effective governance, a Village Monitoring Committee (VMC) was established to regulate and protect the artificial reef area while promoting awareness about sustainable fishing practices. The VMC also plays a crucial role in conflict resolution among fishermen, working in collaboration with local government officials. Through this system, fishing communities have implemented their own social control mechanisms, ensuring adherence to customary laws and practices for the conservation of fishery resources within the artificial reef zone.

2.1. Conservation and Management Initiatives by PLANT

The conservation initiative began with the designation of a 1,000-square-meter core area as an Indigenous and Community Conserved Area (ICCA), where 200 artificial reef structures were deployed for one fishing hamlet, expanding the available habitat to 1,000 square kilometers for marine organisms to colonize. Surrounding this core, a 5,000-square-meter secondary protected area was established, along with a 10,000-square-meter buffer zone, serving as a crucial coastal ecosystem reserve.

2.2. Concept of Artificial Reefs

Marine biological productivity can be significantly increased by expanding the seabed substratum, which provides an ideal habitat for colonizing organisms. Artificial reefs attract small fish initially, followed by larger predatory species. The abundant food supply and secured shelter within the reef structures create optimal conditions for breeding and sustaining aquatic populations.

Traditionally, fishermen have used a method known locally as *Mullam*, where large trees were submerged to serve as rudimentary fish aggregation devices. Building on this practice, the Village Monitoring Committee - VMC has implemented a sustainable fishing system that prohibits the use of unsustainable fishing gear, fiberglass-reinforced plastic (FRP) boats with gill nets, and other destructive fishing methods. To manage fishing pressure, the VMC enforces a roster-based rotation system, limiting the number of fishermen allowed in the fishing zone each day.

The artificial reefs also act as protective barriers for small-scale fishermen by safeguarding their fishing grounds within 5 nautical miles of the shore. The presence of these reef structures deters mechanized trawlers, as their nets become entangled in the reef, leading to financial losses for trawler owners. Consequently, the reef zone serves as an effective natural barrier against over exploitation of marine resources, contributing to coastal biodiversity conservation.

Furthermore, the VMC has successfully preserved the traditional *Padu* system—an equal distribution system for fishing grounds—across neighboring villages. This system promotes equitable access, collective social responsibility in fisheries management, and conflict resolution among fishing communities.

3. Impact of the Initiative

The collaborative efforts of PLANT and local communities have yielded significant ecological and

[3] The Great Sumatra earthquake of 26 December 2004 caused the Indian Ocean tsunami had a significant effect on the southern peninsular region of India and severely affected the coastal regions of state of Tamil Nadu

[4] Fiber Reinforced Plastic Boats

socio-economic benefits across the beneficiary villages.

3.1. Ecological Impact

a. The artificial reef has led to a marked increase in fish population size and species diversity. The newly established ecosystem now supports representatives from seven different phyla, comprising approximately 38 species, including polychaetous annelids, crustaceans, mollusks, coelenterates, and bryozoans. Fish species observed at the reef include carangids, rays, butterflyfish, squirrelfish, groupers, red snappers, catfish, and various small, colorful coral fish such as blue damsels, wrasses, and dumbheads. The estimated average shoal size is around 200 individuals per reef.
b. Samples collected from artificial reefs in 10 villages across Chenglepet district and other reef zones recorded a sessile epibenthic biomass of 2,586 to 3,998 g/m² on horizontal surfaces and 4,821 to 7,992 g/m² on vertical surfaces. The estimated average biomass was 1,983 g/m² on the exposed outer surface of concrete reef structures and 3,813 g/m² on the protected interior surface along the Bay of Bengal.
c. The deployment of 200 artificial reef structures is estimated to reduce annual carbon dioxide emissions by 732 to 2,000 kg.

d. Fossil fuel consumption by fishing vessels has decreased significantly. The estimated reduction in CO_2 emissions per boat per day is approximately 13.25 kg.

3.2. Socio-Economic Impact

a. The artificial reef ecosystem generates an estimated **$190,000** worth of biodiversity products and ecosystem services annually.

b. Fishermen operating in the artificial reef zone catch approximately **3,000 to 5,000 kg of fish per month**, supporting over **3,600 families** in Chenglepet district's fishing villages. The average monthly income of these fishermen has increased to **₹15,000 to ₹20,000**. ($177 to $236).

c. The close proximity of the fishing grounds within the artificial reef zone has led to economic savings by reducing fuel consumption and fishing time.

d. Upon arrival at the shore, women take the lead in auctioning and selling the fish in local markets. Additionally, they have engaged in community-driven environmental activities, such as planting trees, developing home herbal gardens, and using organic manure for cultivation.

e. The estimated revenue generated from fish catch within the reef zone is **₹2.5 to 3 lakh per month**, per village amounting to **₹25 to 30 lakh per annum**. This remarkable income reinforces the sustainability of fishing livelihoods and provides marginalized fishing families with economic security and dignity.

4. Sustainability and Partnerships

The coastline of Tamil Nadu, located on the southeastern coast of the Indian Peninsula, forms part of the Coromandel Coast along the Bay of Bengal and the Indian Ocean. Stretching 1,076 km (669 mi), it is the second-longest coastline in India after Gujarat. The Tamil Nadu coastline encompasses 591 fishing villages across 13 districts.

PLANT, in collaboration with the local community, received support for the project from various organizations, including Nuclear Power Corporation of India Limited of Madras Atomic Power Station - NPCIL MAPS, the Ministry of Environment, Forest and Climate Change, the Central Marine Fisheries Research Institute (CMFRI), the Central Institute of Brackish Water Aquaculture, the Marine Product Export Development Authority (MPEDA), the Central Institute of Fishery Technology (CIFT), Tamil Nadu State Fisheries, and the Ministry of Shipping, Zoological Survey of India, Fisheries Survey of India.

5. Scientific Sea Survey

Before deploying artificial reefs, a comprehensive scientific sea survey must be conducted to identify a suitable seabed location. The reefs should be placed in shallow waters at depths of 6 to 18 meters, within five nautical miles of the shore, to ensure adequate sunlight exposure for photosynthesis. To establish a sustainable fish colony and effectively conserve coastal biodiversity, a minimum of 200 structures per village is required.

To advance the reef project, PLANT NGO presented the success story of its artificial reef initiative to Madras Atomic Power Station (MAPS) in 2012. The

organization proposed that MAPS undertake an artificial reef project in the Kalpakkam region as part of its Corporate Social Responsibility (CSR) efforts to support the livelihoods of local fishermen.

After conducting an in-depth study, MAPS approved the implementation of an artificial reef project in Pudupattinam village as a pilot initiative in 2012. Following the project's success, as evidenced by increased fish catch and higher incomes for fishermen, demand for similar projects grew in neighboring villages. Encouraged by positive feedback from the local fishing community, MAPS expanded the initiative to multiple villages in Chenglepet district. Research indicated that 3 to 5 tons of fish were harvested in the reef area using hook-and-line fishing techniques. It was estimated that each village generated monthly fish catches valued at approximately **₹2.5 to 3 lakhs**. While fish stock availability in the reef zone remained consistent, fishermen could only operate for about eight months each year due to rough sea conditions and fluctuating ocean currents. The underwater video study observed and estimated that 50 tons of diverse marine species are consistently present in the artificial reef zone. To date, Madras Atomic Power Station has However, the tsunami's seismic waves severely damaged this habitat, significantly reducing fish stocks and forcing fishermen to venture farther offshore in search of viable fishing grounds.

Recognizing artificial reefs as a viable solution to restoring fish stocks in nearshore waters, local fishermen urged MAPS to expand its reef deployment efforts in the Kalpakkam and Mahabalipuram regions. Responding to their request, MAPS extended its support to 17 neighboring fishing villages, significantly supported 17 fishing villages in the Kalpakkam and Mahabalipuram regions, deploying a total of 3,450 reef structures within five nautical miles of the shoreline.

A significant milestone of this initiative was its recognition by the Ministry of Environment and Forests under the UNDP GEF SGP project, which was honored with the UNDP India Biodiversity Award in 2016. Additionally, Madras Atomic Power Station received the prestigious Green Tech Award for its contributions to marine conservation.

6. Restoration of Natural Fishing Grounds

A study conducted in the Kalpakkam and Mahabalipuram regions revealed that fishermen practicing hook-and-line fishing required additional reef structures for sustainable fish harvesting. Before the 2004 tsunami, these fishermen relied on nearby fishing grounds within a five-nautical-mile radius. The seabed in this area was characterized by rocky and sandy substrates, with accumulations of barnacles and seashells that naturally fostered fish breeding.

enhancing marine biodiversity and sustaining local livelihoods. The reefs were fabricated in the fishing villages and deployed at the bottom of the sea by using the FRP boats and Marine Sail Vessel like Barge. The following Google map and table outlines the number of beneficiary villages, while the accompanying Google Map provides the latitude and longitude of each deployment site. Each Fishing village 200 to 210 reefs were deployed at the off shore of Kalpakkam and Mahabalipuram regions.

Fig I

Geographical spread

The below table indicates the consolidated reef sites and total number of reef deployed in the contiguous area in Chengalpattu districts.

Table I

Sl. No	Name of the village	No. of Reefs	Latitude	Longitude
1	Pudupattinam	210	N- 012°.27.814	E- 080°.11.684
2	Meyyur	210	N- 012°.31.641	E- 080°.12.493
3	Sadras North	210	N- 012°.29.919	E- 080°.12.048
4	Sadras South	210	N- 012°.29.691	E- 080°.12.225
5	Uyyali Kuppam	210	N- 012°.27.232	E- 080°.11.818
6	Kokilamedu	200	N- 012°.34.436	E- 080°.13.367
7	Pudu Edaiyur	200	N- 012°.39.017	E- 080°.14.939
8	Pattipulam	200	N- 012°.40.314	E- 080°.14.794
9	Pudu Kalpakkam	200	N- 012°.43.441	E- 080°.16.325
10	Nemili Kuppam	200	N- 012°.42.288	E- 080°.16.328
11	Kattu Kuppam	200	N- 012°.41.022	E- 080°.15.828
12	Devaneri	200	N- 012°.37.936	E- 080°.14.425
13	Venpurusam	200	N- 012°.35.468	E- 080°.13.705
14	Pudu Nadu Kuppam	200	N 12° 23' 258"	E 080° 08' 523"
15	Kadalur Chinna Kuppam	200	N 12° 25' 690"	E 080° 10' 567"
16	Angalamman Kuppam	200	N 12° 24' 271"	E 080° 08' 954"
17	Kadalur Ali Kuppam	200	N 12° 24' 250"	E 080° 09' 156"
	Total	3450		

7. Implementation Process

Intervention Strategies and Activities:

1. Conduct a benchmark survey on population structure, socioeconomic conditions, and livelihood status in the selected fishing villages.
2. Engage with Panchayat leaders to discuss the technologies and techniques to be introduced for community benefit and planning.
3. Form various committees for the execution and supervision of different program components, involving both villagers and PLANT representatives.
4. Fabricate the required number of artificial reef structures with technical support from PLANT.
5. Conduct a survey to identify suitable seabed locations for reef deployment, in collaboration with CMFRI and PLANT.
6. Deploy artificial reefs at the selected sites under the supervision of PLANT, with active participation from the fishing community.
7. Monitor and study the maturation process of artificial reefs to determine the optimal period for fish harvesting.
8. Introduce hook-and-line and trap fishing methods to fishermen, with training support from CFT Cochin and traditional trap fishers from Kilakarai.
9. Train fishermen to fabricate their own hook-and-line and trap fishing gear.
10. Assess fish catch composition and effort in both artificial reef areas and non-reef areas for comparison.
11. Introduce appropriate post-harvest methods, such as ice boxes and deep freezers, through linkages with MPEDA.
12. Facilitate market access for fresh fish, dried fish, and value-added products through women's Self-Help Groups (SHGs).
13. Conduct a mid-term assessment of project progress and perform another socioeconomic survey at the end of the first year.
14. In the second year, continue monitoring and evaluate the socioeconomic impact of the project.
15. Develop withdrawal strategies to ensure self-sustainability of the initiative by the community.

8. Monitoring and Evaluation Process Follow-up Programme

After the deployment of reefs, the PLANT team conducted regular field visits to all beneficiary villages to monitor the reef locations. Fishermen were advised to refrain from any fleet operations or fishing activities for six months, a designated incubation period allowing biological maturation. During this time, the reefs developed biological films consisting of algae, barnacles, ascidians, and other marine organisms, enhancing biomass production and attracting a variety of fish species for reproduction. Fishing activities were recommended only after 9 months, in the ninth month post-deployment. Additionally, fishermen were instructed never to use inappropriate fishing gear in the reef zone to ensure long-term conservation.

PLANT conducted a post-impact assessment of the artificial reef project using underwater video surveys. Professional scuba divers were engaged to document reef maturation and biological development. The underwater video footage is included in the project report. The Artificial Reef Monitoring (ARM) committee regulates fishing activities in the reef zone, allowing only 10 boats at a time to ensure sustainable use of biological resources. Each boat is permitted to catch between 10 and 15 kg of fish per trip to prevent overexploitation. Additionally, fishermen are encouraged to contribute 10% of their earnings to the village Panchayat as a community fund for future development initiatives.

9. Key Challenges Addressed

Key challenges include securing additional funding to replicate this project in other coastal states, improving coastal biodiversity, and enhancing marine fisheries resources. Price inflation and natural calamities also pose challenges to implementation. A dedicated government budget for large-scale deployment is recommended. Coastal industries should consider

adopting artificial reef projects as part of their CSR initiatives, and state pollution control boards should mandate such projects in their consent orders. Furthermore, community-led monitoring strengthens project sustainability.

10. **Impact Created**

High-resolution photographs, statistical data, and success stories from beneficiaries will be included to illustrate the project's impact. If available, detailed analysis and case studies will highlight the improvements in marine biodiversity and socioeconomic benefits to the fishing community.

11. **Biological Impact**

Within six months of installation, artificial reefs fostered bacterial bio-films, algae, seaweeds, barnacles, sponges, corals, crustaceans, soft and hard corals and various fish species. These developments significantly enriched marine biodiversity and enhanced fishery stocks. Underwater videography conducted by PLANT revealed an abundance of marine life, including rare species and ornamental fish. Notably, the presence of white and pink bush coral (Oculina varicosa) and octocorals and abundance of sea fans was observed, providing crucial habitat for commercially valuable fish species. These slow-growing corals, likened to underwater redwood forests, contribute to a unique and biologically diverse ecosystem previously undocumented off the Chenglepet coast.

12. **Result Indicators for the Deployment of Artificial Reefs**

a) A primary core surface area of 1,000 sq. m is established as an Indigenous and Community Conserved Area (ICCA) for biomass production, supported by 200 artificial reef structures within a single artificial reef zone.
b) This 1,000 sq. m area provides space for settlers and foulers to colonize, enhancing biodiversity in the artificial reef installation site.
c) A secondary core protected area of 5,000 sq. m is created, supporting secondary and tertiary producers within a short period of six months.
d) A buffer zone of 10,000 sq. m is established, contributing to coastal ecosystem conservation and supporting a diverse biomass.
e) 10,000 sq. m of dedicated space is available for the production of sustainable biomass, free from the negative impacts of mechanized bottom trawling within the artificial reef zone.
f) Each artificial reef structure produces between 2.5 kg and 5 kg of biomass per square meter per year.
g) A single artificial reef structure can sequester between 3.66 kg and 10 kg of CO2 annually.
h) The deployment of 300 artificial reefs has led to a reduction in annual CO2 emissions by 1,098 to 3,000 kg.
i) Significant savings in fossil fuel consumption and reduction in fishing time are achieved due to the proximity of the artificial reef fishing ground.
j) Each fishing boat saves 5 liters of fossil fuel per day, as the fishing ground is located within 5 km of the fishing village, eliminating the need for long-distance fish hunting.
k) Consequently, the CO2 reduction per boat per day is estimated at approximately 13.25 kg.
l) With 150 boats operating daily, the total CO2 reduction amounts to 1,987.5 kg per day.
m) Additionally, these 150 boats collectively save 750 liters of diesel daily, as they fish near the artificial reef zone, utilizing wind power or manual rowing whenever feasible.
n) The estimated daily Greenhouse Gas (GHG) reduction is 10.5 metric tons.
o) The estimated fuel cost savings per day is Rs. 37,500/- ($750/-) due to reduced fuel consumption.

This structured deployment of artificial reefs demonstrates significant environmental and economic benefits, promoting sustainability in coastal fisheries and marine conservation.

13. **Economic Benefit**

As an outcome, fishery resources have significantly increased over a maturation period of one year. Fishermen operating in the artificial reef zone catch approximately 3,000 to 5,000 kg of fish per month. This innovative intervention continues to support 200 to 300 families directly in a single village, while an additional 1,200 families benefit indirectly.

The Tamil Nadu State Fisheries Department has recognized the efforts of the federation and has

standardized this participatory fabrication and deployment model for replication in other locations. As a result of this project's overwhelming success, the Government of Tamil Nadu has sanctioned more artificial reef projects across the state.
The fishing effort within a single artificial reef zone has increased to 3 to 5 tons per month, generating an estimated revenue of **₹2.5 to 3 lakhs**, benefiting 1,200 families. This translates to an average income of Rs. 15,000 to Rs.20,000 per family, providing a sustainable livelihood.

This initiative has significantly improved the well-being and economic status of the fishing community, paving the way for sustainable fishing and livelihood development. Additionally, recognizing its broader climate change mitigation potential, both the state government and corporate CSR initiatives are actively promoting artificial reef projects to support fishing communities in Tamil Nadu while addressing environmental concerns.

14. Management and Scaling Up of Artificial Reefs

To ensure the long-term sustainability of artificial reefs, it is essential to establish regular maintenance and management in the installed areas. The presence of fishermen from other villages who fish in the reef zone using inappropriate nets poses a risk of damaging the reefs. When fishing nets become entangled in the reef structures, they can cause mass fish mortality, leading to foul odors and forcing marine species to migrate away from the area.

As a preventive measure, it is proposed to train village youth in scuba diving, enabling them to periodically clean entangled nets from the reef zone. Additionally, they can promote scuba diving as an ecotourism activity, generating an alternative source of income. The PLANT organization plans to introduce this initiative in the next phase of its project, submitting a proposal to Madras Atomic Power Station (MAPS) as part of its youth skill development program. The project's location in Mahabalipuram on East Coast Road (ECR) offers vast potential for ecotourism, which could further contribute to reef conservation efforts.

The implementing agency, PLANT, is also advised to conduct regular site visits to beneficiary villages to assess the project's impact through fish catch data collection, training programs, and conflict resolution mechanisms. Additionally, MAPS is encouraged to commission a scientific impact assessment study to evaluate the long-term effectiveness of artificial reefs.
Several other villages have requested MAPS to support new artificial reef projects. The PLANT organization has encouraged village Panchayat to submit petitions to the MAPS CSR team, advocating for further expansions. Given the success of this community-driven, science-based initiative, it is recommended that Nuclear Power Corporation of India Limited (NPCIL) replicate this artificial reef model in other NPCIL coastal project sites to enhance marine biodiversity and fisheries resources.

15. Future Prospects and National Impact

Scaling up this project based on lessons learned from previous implementations is critical for expanding its benefits across coastal states in India and globally. Systematic documentation of successful models and findings could facilitate the development of national fisheries policy guidelines, enabling widespread replication. This initiative has the potential to boost India's fish export industry, contribute to national GDP growth, and enhance food security.[5] In 2024, The fisheries sector contributes approximately 1.09% to India's total Gross Value Added (GVA) at constant prices, and over 6.724% to the agricultural GVA. In comparison, in 2010-11, the fisheries sector contributed 0.79% to India's total GDP and 4.39% to the agriculture sector's GDP[6]. This significant growth is attributed to the introduction of innovative projects such as artificial reefs, open-sea cage culture, and aquaculture farming activities, which have enhanced marine sector productivity.

The artificial reef project has significantly transformed the coastal ecosystem, promoting marine biodiversity conservation and sustainable fisheries in Kalpakkam and Mahabalipuram. It has also improved livelihoods, empowering fishing women by allowing them to sell fresh fish at fair prices, eliminating middlemen, and fostering savings habits. Additionally, village panchayats have established common funds, with fishers contributing 10% of their income to support local development initiatives.

Beyond fisheries, the reefs serve as natural barriers against seismic waves, mitigating coastal erosion and protecting fishing villages. This project has truly made a global impact on coastal conservation and community livelihoods.

Dr. R.T. John Suresh, founder of PLANT and an expert in artificial reef projects, has presented this successful model at national and international forums, exhibitions, and conferences. As a result, the Indian

[5] https://www.fao.org/fishery/en/facp/ind?lang=es

[6] https://dof.gov.in/sites/default/files/2020-01/India%20Profile%20updated_0.pdf

government, through the Ministry of Environment, Forest and Climate Change (MoEF&CC) and UNDP, has adopted this project as part of national fisheries development policy. The Tamil Nadu Fisheries Department has allocated separate budget to scale up artificial reef projects along the Tamil Nadu coast.

For further inquiries, please contact Dr. R.T. John Suresh at plant_sures@yahoo.com or +91-9840740929. Email: plant_suresh@yahoo.com.

These below references are closely related to your article on artificial reefs. They cover key aspects relevant to your study, including:

1. *Ecological Benefits – How artificial reefs enhance biodiversity, fish biomass, and marine conservation.*
2. *Fisheries Enhancement – The role of artificial reefs in increasing fish catch and supporting sustainable fishing.*
3. *Socioeconomic Impacts – The impact on local fishing communities, livelihoods, and economic benefits.*
4. *Carbon Sequestration & Climate Change – How artificial reefs contribute to reducing CO_2 emissions.*
5. *Reef Management & Sustainability – Strategies for maintaining artificial reefs, preventing damage, and scaling up.*

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Pictures

Before-after the deployment of Reefs

After Deployment (three year old reef)

Fish stock availability in the reef area


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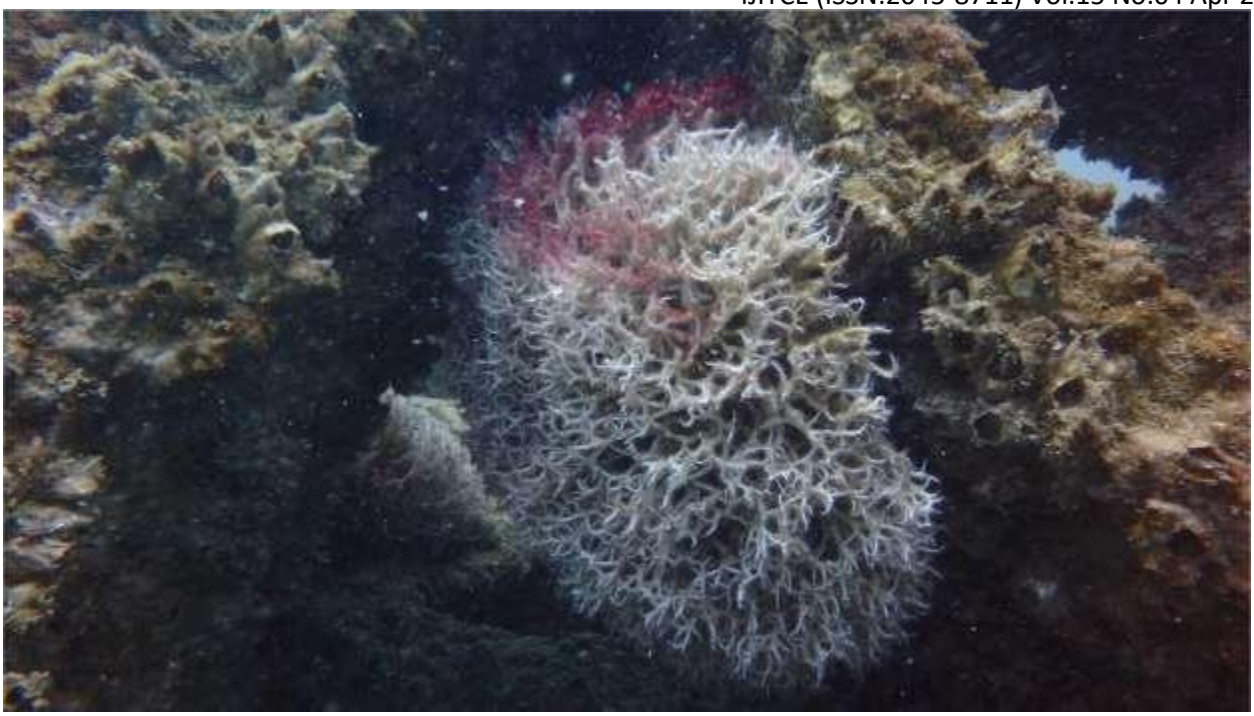
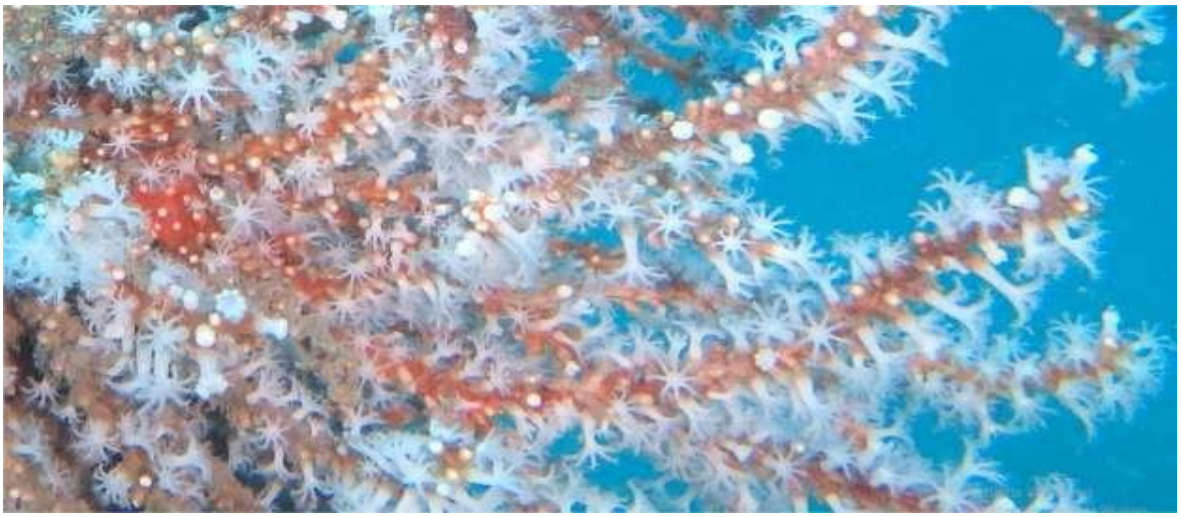
Activate Windows



Oculina Coral and rare species like Lion fish and sea feather settled in the reef area

White Telesto, an octocoral (*Carijoa riisei*), has settled on the reef



Chairman and Managing Director inaugurating the Artificial Reef Deployment at Kalpakkam.

Reefs deployed to save power plant house 50 marine species

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A series of concrete blocks — artificial reef — deployed a few kilometres into the sea by the state fisheries department has turned out to be a good sign for the fishermen in Nemmilikuppam

D Karunakaran, 40, of Nemmilikuppam was among the 160 fishermen who would often return home after spending the day at sea with a catch that barely would sell for ₹1,000. However, that changed in the last few years after artificial reefs became home to many fish.

Fishermen claim to have a catch worth at least five times more than what they used to earn earlier.

The artificial reefs were deployed between 2012 and 2020 around 9km into the sea at 18m depth across a 30km stretch from Pudukalpakkam near Kovalam in the north to Angalamman Kuppam near Koovathur in the south covering Madras Atomic Power Station (MAPS) at Kalpakkam, the township and 17 other coastal villages. The blocks, expected to protect the coast from rough waves, and erosion, are now home to nearly 45 marine species, including commercially important fish varieties. The reef deployment was carried out as part of a project funded by MAPS and implemented by Chennai-based NGO Partici- patory Learning Action Network and Training (PLANT).

"It was part of our CSR activities. The reefs were deployed along the coast from the power plant to the township a few years ago and now it's home to numerous species," said Shub- h a Murthy, technical services group, MAPS.

RT John Suresh, the founder of PLANT, said a recent underwater survey showed that the reefs have attracted many rare, commercially important and ornamental species.

"A variety of the white and pink hard coral reefs otherwise called Oculina Varicosa or the ivory tree corals are growing in the reef structures in a non-coral region. These corals are attracting fishes including commercially important fish species to the region as they act as a habitat," he said.

It all started with reefs shaped in circular, triangles and rectangles being first deployed in one village in 2012 and later extended to 17 coastal villages in and around Kalpakkam. Around 200 concrete blocks have been deployed near each coastal village. Suresh said soon after the deployment the reefs saw algae, and microorganisms started settling, which began attracting other marine species. Eventually, they observed seaweeds, barnacles, ascidians, sponges, hard and soft corals, gorgonids, starfishes, sea urchins, sea cucumbers, bivalves, chunks, crabs, lobsters, other crustaceans followed by a variety of fishes and other vertebrates.

VARIETIES OF FISH

Nemmelikuppam fisherman Karunakaran said they are seeing more fish varieties like **paarai (mackerel) kalava (reef cod), vavval (Pomfret) and kilicha (Perch)** now compared to before the reefs were deployed when they would only find crabs and thumbli (lizardfish) fish. "Also, we don't have to venture too far into the sea because we get good yield near the reefs around 4km from the coast," he said.

Assessing and Mapping Shallow Water Seabed Suitability for Artificial Reef Deployment: A Case Study in Palk Bay, Rameswaram, Ramanathapuram District, Tamilnadu, India.

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Abstract

PLANT is a national-level voluntary organization dedicated to biodiversity conservation and the sustainable livelihood development of marginalized communities in India. PLANT core focus areas include biodiversity conservation, sustainable natural resource management, innovation, advocacy for marginalized communities, and research and policy advocacy. The first Author is a founder director of PLANT Trust.

PLANT has partnered with the UNDP GEF SGP program for nearly two decades, promoting the conservation of coastal biodiversity and the sustainable use of marine resources to support the livelihood development of fishing communities. During the UNDP GEF SGP OP5 project, PLANT deployed 300 artificial reefs in two fishing villages: Chennai Fishing Harbor and C-Pudupet in Cuddalore district. The success of this project has been widely demonstrated to multiple stakeholders, encouraging the replication of the artificial reef initiative in other coastal states across India.

Additionally, PLANT's with the support of Ministry of Environment and Forest and Climate Change, Government of India, Fisheries Department, UNDP, GEF, SGP has taken several efforts in advocacy and presentations to relevant stakeholder departments through publications and national and international events have influenced policymakers. This has led to the inclusion of artificial reefs in the fisheries policy, with
a dedicated budget allocated under the Prime Minister's scheme to implement reef projects in all coastal states of India. In addition the coastal industries also included the reef project in their corporate social responsibility budget to implement in their nearshore sea water to enhance the fisheries resource and conserve the coastal biodiversity.

Currently, with the support of UNDP GEF SGP OP7 through TERI Delhi, PLANT is implementing a similar project. This project

involves the fabrication and deployment of artificial reefs to enhance fisheries resources and enrich coastal biodiversity in eight fishing villages off the coast of Palk Bay, Rameshwaram, in Ramanathapuram District, Tamil Nadu.

Three hundred artificial reefs have been fabricated and deployed at three different locations adjacent to the beneficiary fishing villages, namely Erakadu, Karaiyur, Kudiyiruppu, Mangadu, Olaikuda, Serankottai, Vadakadu, and Sembai in Rameshwaram island. PLANT has conducted scientific sea surveys to identify suitable sea beds for the deployment of artificial reefs. A detailed sea survey study report outlines the deployment sites and community management plan to conserve the artificial reef zones as an Indigenous Community Conservation Area (ICCA).

Keywords: Sea grass, Coral reef, Artificial reef, ICCA, biodiversity. Sea Survey, UNDP, GEF, SGP.

1. Introduction:

PLANT is a Nonprofit Volunteer organization based at Chennai, India, working for the Conservation of Biodiversity and sustainable development of marginalized communities in India for past two decades with an aim to promote the following strategies in line with sustainable development goals.

- Conservation of Biodiversity and sustainable use of biological resources
- Coastal resource enhancement by deployment of reefs – “Reef for fish forever programme”, Sea Weed Culture, Open Sea Cage Culture, Mangrove Afforestation, Conservation of Sea grass, Coral reef conservation, Beach restoration and sea turtle conservation.
- Monitoring the coastal biodiversity, Plastic Waste Management, Marine Pollution control, Environment Awareness building.Community organization, skill development, promotes Entrepreneurship Development Programme, Livelihood Development, women empowerment and child development.
- Research and Advocacy, publications, uses of technology and innovation in all our interventions,

The artificial reef project has been initiated by PLANT Trust with the funding support of Ministry of Environment and Forest & Climate Change, GoI and UNDP India in the year 2016 under GEF UNDP Small Grant Programme. This project continued in GEF UNDP Small Grant Programme OP7 and deployed 300 artificial reefs to conserve the coral ecosystem and also to improve the sustainable fishing for the livelihood development of fishermen at Rameshwaram.

The success of the program has been scaled up and replicated in more than 50 fishing villages and deployed nearly 5220 reefs at the off coast of Tamilnadu, India with the support of Corporate Social Responsibility fund, International fund under Australian Direct Aid Programme, and Government fund. The success of the project is well documented and has been widespread to multi stakeholders groups to adopt this proven technology to improve the marine eco system and conservation of coastal biodiversity as a climate action programme. PLANT is promoting coastal and marine conservation activities such as coral restoration, Mangrove Afforestation, Fisheries start up business for the livelihood development, youth skill training, research and advocacy in India.

2. UNDP GEF SGP OP7 Project:

In July 2023, PLANT was selected by the Ministry of Environment, Forest and Climate Change, UNDP, and the GEF.SGP programme to deploy 300 artificial reefs off the coast of Rameshwaram. This project, aimed at benefiting hook-and-line fishermen from eight fishing villages such as Erakadu, Karaiyur, Kudiyiruppu, Mangadu, Olaikuda, Serankottai, Vadakadu and Sembai in Rameshwaram island. The structures are fabricated and deployed at the off shore of Rameshwaram. , PLANT Trust has conducted detailed sea survey at twele locations and finally chosen three locations at Rameshwaram coast near to the beneficiary fishing villages before the deployment of artificial reef.

3. Statement of Problem

The eight beneficiary fishing villages are small communities located in the contiguous coastal area of Palk Bay on the eastern side

of the island, with a combined population of approximately 5,000 people. The residents of these villages depend entirely on fishing and related activities for their livelihood. Women in these communities are primarily engaged in selling fish, making dried fish, collecting seaweed, and gathering ornamental shells.

The fisherfolk in these villages practice small-scale fisheries in the nearshore marine waters, within their native fishing grounds extending up to five nautical miles. Most of the fishers use only FRP (Fibre-Reinforced Plastic) boats, with an estimated 150 to 200 boats available across all beneficiary villages. Importantly, the hook-and-line fishermen use small, non-mechanized fishing vessels made from thermocol, operating within the same five nautical mile range. These fishermen, from low-income groups, face significant risks while using these small vessels for their fishing activities.

Additionally, trawlers from Pamban and other areas operate within the nearshore marine area, often encroaching on the native fishing grounds of traditional fishermen. These trawlers cause severe damage to the coastal ecosystem, including seaweed, seagrass, and coral reefs.

In this context, deploying artificial reefs can act as a protective barrier to conserve the nearshore coastal ecosystem, creating an Indigenous community conservation area. Once artificial reefs are placed in suitable sites, they will enhance coastal biodiversity and rejuvenate coral reefs, seaweed, and seagrass ecosystems. Since artificial reefs are heavy concrete structures deployed on the sea bottom, trawlers will be unable to operate in the reef zones and nearshore marine waters without risking damage to their nets.

4. Objectives

The primary objective of the grant is to fabricate and deploy 300 reefs in the near shore off Rameshwaram to enhance the marine fishery resources and to conserve the coastal biodiversity for the sustainable fishing for the livelihood development of the fishermen. The study indicates that on how the suitable sea bed locations were identified for deployment of reefs in three clusters/zones for all these proposed villages. A detail sea survey report is incorporated in this study.

Secondary Objectives

- to fabricate and deploy 300 artificial reefs at the off coast of Erakadu, Karaiyur, Kudiyiruppu, Mangadu, Olaikuda, Serankottai, Vadakadu and Sembai at Rameshwaram, Ramnad District, Tamilnadu, India to enhance the marine fishery resources and to conserve coastal bio-diversity
- to integrate reef conservation and enhancement of fishery resources with an aim to increase the coastal ecosystem and fish production through adoption of people friendly technologies
- to Increase the biomass production and Preserve the endangered species in Reefs zone
- to create coastal conservation awareness among fisher folk at Rameshwaram island in Tamilnadu
- Create conservation awareness on responsible fishing

5. Artificial Reefs

Artificial reefs are man-made structures deployed on the sea bottom to increase the surface area available for various marine organisms and create shelter for fish and lobsters to breed and feed. These structures mimic natural reef habitats, providing additional substrate for marine life and enhancing biodiversity.

There are three primary types of artificial reef structures:

1. Ring Ornamental Fish Module
2. Ferro Concrete Triangle Reef Fish Module (Somosa Module)
3. Triangular Grouper Module

The construction features of Artificial Reefs

Artificial reefs are constructed from materials such as concrete, sand, cement, blue metal, and steel, designed to withstand marine environments and provide a stable

platform for marine life to colonize. For example, a groper or ferro-concrete artificial module provides a surface area of 6 sq.m in three dimensions. When a reef is deployed at the bottom of the sea, 1 sq.m of the reef base is placed on the seabed, while the remaining 5 sq.m is available for biomass production.

Deploying 200 artificial reef structures in one artificial reef zone creates a primary core surface area of 1000 sq.m. This area serves as an Indigenous and Community Conserved Area (ICCA), promoting basic biomass production. Additionally, the 1000 sq.m of surface area available to settlers and foulers for colonization significantly enhances the biodiversity of the region where the artificial reefs are installed.

6. **Artificial Reefs Help Restore Degraded Marine Ecosystems**

Artificial reefs enhance marine ecosystems by providing new habitats for marine life. Within six months of installation, biological processes begin with the formation of bacterial biofilms, followed by the settlement of algae, seaweeds, sea grass, barnacles, ascidians, sponges, hard and soft corals, gorgonids, starfish, sea urchins, sea cucumbers, bivalves, chanks, crabs, lobsters, and other crustaceans. This succession of settlers creates a rich and diverse habitat that attracts a variety of fish and other vertebrates. The artificial reef area becomes a hotspot for marine life, resembling an organic soup that continuously attracts and sustains various species.

7. **Artificial Reefs Restore Natural Coral Reefs Over Time**

Over time, artificial reefs can evolve to resemble natural coral reefs, especially if a natural coral reef is nearby. This reduces fishermen's dependence on natural coral reefs and provides an alternative livelihood for coastal communities. Additionally, artificial reefs support a healthy population of ornamental fish, which can be harvested for additional income. They can also become sites for ecotourism, offering further economic benefits. Moreover the native speicies such as Seela, Paarai, Nagarai, Vaalai, Katthalai, Panna, Vilameen, Sudai, Thontan and Thirukai Sudai and Thontan Seela, Paarai, Nagarai, , Katthalai, Panna, Vilameen, Sudai will be enhanced massively.

8. **Economic and Environmental Benefits**

Artificial reefs established near fishing villages allow fishermen to travel shorter distances, saving fuel and reducing expenses. Fishing can be done more quickly, ensuring better-quality fish and higher market prices. This contributes to the sustained economic growth of coastal communities.

9. **Long-Term Ecological Impact**

Artificial reefs contribute to sustainable livelihoods and enrich coastal biodiversity. They act as marine protected areas, as mechanized fishing vessels cannot operate in reef zones without risking severe damage to their equipment. Beneficiaries often adopt sustainable fishing practices, such as hook-and-line fishing, ensuring a balanced harvest of fishery resources.

The deployment of artificial reefs offers numerous benefits: conservation of marine ecosystems, improved fish catch, fuel savings, year-round fish availability, better economic returns for coastal fishermen, and sustainable livelihoods. These reefs enhance coastal biodiversity and provide significant ecological and economic benefits, making them a valuable tool in marine conservation and resource management.

10. **Community Involvement and participation in Artificial Reef Deployment**

This project is purely community-driven, aimed at empowering the fishing community in planning and executing the project components. It involves the absorption of new fishing technologies, post-harvest processing and handling techniques, and new market avenues for value-added products to maximize economic benefits. Once deployed, the artificial reefs require minimal management as the structures are safely situated on the sea floor. However, it is important to use only hook-and-line fishing methods in the reef zones to ensure sustainable harvests. This approach can be managed effectively by fishermen who regularly go to sea, preventing over-exploitation of fishery resources. The community's involvement in the

implementation process has been crucial to achieving the project's goals. Their dedication and commitment have fostered a sense of ownership, ensuring long-term sustainability and self-management of the project.

11. **Addressing External Threats**

To prevent inappropriate use of crafts and gears, the beneficiary group proactively communicates with other trawl fleet operators, requesting them to avoid fishing in the reef zones. This helps conserve coastal biodiversity and supports the livelihoods of local fishermen by promoting sustainable fishing practices. The beneficiary group maintains cordial relationships with all stakeholders to protect the reef zones effectively.

12. **Monitoring and Support**

13. The Reef Monitoring Committee periodically monitors the reef zones and collects fish catch data to analyze the project's impact with PLANT's technical guidance. The committee regularly gathers data on fishing efforts from fishermen, comparing current catches with previous data to assess improvements in fishery resources. Other stakeholders, such as the fisheries, wildlife and forest, and coast guard departments, are informed about the project and provide support and cooperation during its execution.

14. **Impact of Artificial Reef Deployment**

Economic and Ecological Benefits

The deployment of artificial reefs has significantly increased fishery resources over a maturation period of one year. Fishermen operating in the artificial reef zones have reported catching between 3,000 kg to 5,000 kg of fish per month. This innovative intervention supports over 5000 families in Rameshwaram in Ramanathapuram district.

The Tamil Nadu State Fishery Department has recognized the success of this initiative, standardizing the participatory fabrication and deployment module to replicate the project in other sites. As part of a co-finance component, the Australian Consulate General in Chennai has supported the deployment of 100 additional artificial reef structures for the Kasimedu fishermen, continuing the efforts initiated under OP 5 GEF SGP project.

15. **Statistical Impact**

In all three artificial reef zones, fishing efforts have increased to up to 5 to10 tons per month, translating to a monthly income of approximately Rs. 15 Lakhs for 1,200 families. On average, each family earns around Rs. 12,500 to Rs.15,000 per month from fishing, providing a sufficient income to support their livelihoods. This solution has greatly improved the wellbeing and livelihood status of the fishing community, creating a path for sustainable fishing and livelihood development.

16. **Government and Corporate Support**

The success of this project has led the Tamil Nadu government to sanction additional artificial reef projects across the state. The project has also attracted corporate CSR support, promoting the implementation of artificial reefs for fishing communities. For example, the Madras Atomic Power Station of Nuclear Power Corporation India Limited has replicated the artificial reef project in 17 villages, deploying over 5,000 structures in the Mahabalipuram and Kalpakkam regions through PLANT Trust.

17. **Deployment of Artificial Reef**

This section focuses on the deployment process of artificial reefs, including site selection through scientific sea survey, design considerations, materials used, and monitoring protocols.

18. **Sea survey**

Sea Survey to Identify Suitable Locations to Deploy Artificial Reef at Rameshwaram, Ramanathapuram District, Tamilnadu, India.

The Ministry of Environment, Forest and Climate Change (MoEF&CC), in

collaboration with the United Nations Development Programme (UNDP), Global Environment Facility (GEF), and Small Grants Programme (SGP) TERI and PLANT, initiated the deployment of artificial reefs at the Rameshwaram coast. A survey was conducted to identify suitable sites for the deployment of artificial reefs. The project focuses on enhancing marine biodiversity and supporting local fisheries in the Rameshwaram area of the Ramanathapuram District in Tamilnadu. The survey, conducted on June 12, 2024, assessed three sites for their suitability based on various environmental parameters. The survey team surveyed at the nine stations with the support of the native fishermen and finally chosen three suitable sites for the deployment of the artificial reef which are mentioned below.

Scientific Interpretation

The survey involved detailed observations and measurements at three potential sites for artificial reef deployment. The key parameters studied included geographic coordinates, distance from the shore, depth, number of reefs to be deployed, and the type of sea bed.

Fig I – Google map indicate the three different location for the deployment of Artificial Re

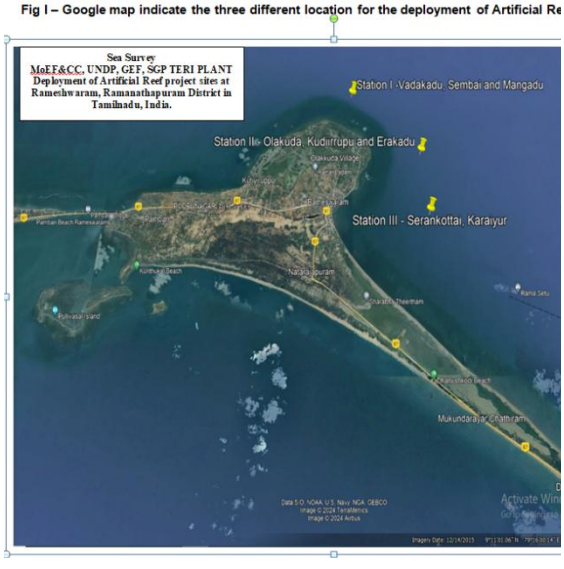

Table I

DISTRIBUTION OF GPS COORDINATES

Sl.No	Survey Date & Time	Name of the Villages	Latitude	Longitude	Distance from Shore (KM)	Depth
1	12/06/2024 10:06 AM	Mangadu, Sembai & Vadakadu	9.333939° (9° 20' 2.18" N)	79.316486° (79° 18' 59.349" E)	2.07	6
2	12/06/2024 08:47 AM	Olakuda, Kudiiruppu & Erakadu	9.310308° (9° 18' 37.109" N)	79.360494° (79° 21' 37.778" E)	3.03	6.6
3	12/06/2024 07:47 AM	Serankotai, Karaiyur	9.279421° (9° 16' 45.916" N)	79.359907° (79° 21' 35.665" E)	5.18	6.1

Site 1: Mangadu, Sembai & Vadakadu
Coordinates: 9.333939°N, 79.316486°E
Distance from Shore: 2.07 km
Depth: 6 meters
Number of Reefs: 100
Sea Bed: The site features a strong sandy rocky bed with no presence of corals or sea grass. This type of substrate provides a stable foundation for artificial reef structures, promoting colonization by marine organisms.

Site 2: Olakuda, Kudiiruppu & Erakadu
Coordinates: 9.310308°N, 79.360494° E
Distance from Shore: 3.03 km
Depth: 6.6 meters
Number of Reefs: 100
Sea Bed: Similar to Site 1, this site also has a strong sandy rocky bed, devoid of corals and sea grass. The rocky substrate is beneficial for the stability and longevity of artificial reefs.

Site 3: Serankotai, Karaiyur
Coordinates: 9.279421°N, 79.359907° E
Distance from Shore: 5.18 km
Depth: 6.1 meters
Number of Reefs: 100

Sea Bed: This site has a strong sandy bed with no corals or sea grass. The sandy substrate, while less stable than rocky beds, can still support artificial reefs, particularly with appropriate anchoring techniques.

Deployment Process

The implementing agencies adopted various mechanisms for deploying artificial reefs offshore. After selecting suitable sites, the deployment

locations are marked using GPS coordinates. The deployment process depends on the quantity and type of reefs to be deployed. For quantities less than 100, with lightweight reefs such as ring and ferro-concrete modules, the reefs are deployed using small traditional craft. For larger quantities, such as 200 or more structures that include all three types of modules, a marine vessel or barge is used to deploy the artificial reefs at the specified locations within a day.

Conclusion

The survey identified three suitable sites for the deployment of artificial reefs in the Rameshwaram area. All sites are characterized by strong sandy or sandy rocky sea beds, which are conducive to the establishment and stability of artificial reefs. The absence of corals and sea grass suggests that these areas are suitable for reef deployment without negatively impacting existing marine ecosystems. The deployment of artificial reefs at these sites is expected to enhance marine biodiversity, provide habitats for various marine species including sea weed, sea grass and coral reefs, and support local fisheries.

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11.

Sustaining India's Coastal and Marine Ecosystems: Challenges, Strategies, and Pathways to Resilience". A Study.

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Astract
India's coastal and marine ecosystems play a crucial role in sustaining biodiversity, supporting fisheries, and providing livelihoods to millions. However, these ecosystems face significant challenges, including overfishing, industrial pollution, habitat destruction, and climate change. The fishing community, particularly small-scale and traditional fishers, struggles with declining fish stocks, financial instability, and lack of access to alternative livelihoods. Women and marginalized groups remain underrepresented in decision-making and face socio-economic vulnerabilities.

To address these issues, the conservation and management of Marine Protected Areas (MPAs) must be strengthened through community participation, sustainable fishing practices, and biodiversity conservation initiatives. Restoration and sustainable management of coastal landscapes, including mangroves, seagrass beds, and coral reefs, are essential for ecosystem resilience. Climate adaptation measures, data-driven governance, and financial sustainability models are critical in securing long-term conservation goals.

Engaging diverse stakeholders—including government agencies, research institutions, NGOs, and local fishing communities—is vital to improving coordination and policymaking. The adoption of innovative technologies, responsible deep-sea fishing practices, and ecosystem-based fisheries management (EAFM) will further promote sustainability. Special emphasis must be placed on empowering women and youth in fisheries governance, conservation efforts, and livelihood development.

Finally, financial mechanisms such as public-private partnerships, disaster preparedness funds, and access to credit for small-scale fishers will strengthen economic resilience. Holistic and inclusive conservation strategies, aligned with national and global sustainability goals, will ensure the protection and prosperity of India's coastal and marine ecosystems for future generations.

Keywords: Coastal Conservation, Marine Protected Areas, Sustainable Fisheries, Climate Adaptation, Biodiversity, Ecosystem-Based Management, Women and Youth Empowerment, Financial Resilience, Stakeholder Engagement

1. Introduction

Challenges in Coastal and Marine Ecosystem Conservation and Management in India

1.1. Indian Fisheries

Marine fisheries and aquaculture are crucial to India's food security, nutrition, employment, and economic growth. The sector provides livelihoods to approximately 16 million fishers and fish farmers at the primary level, with nearly double that number engaged along the value chain. As an affordable and protein-rich food source, fish plays a significant role in addressing hunger and malnutrition. The sector has immense potential to significantly increase fishers' and fish farmers' incomes, as envisioned by the government.
India has vast and diverse fisheries resources, spanning deep-sea waters, lakes, ponds, rivers, and more than 10% of the world's fish and shellfish biodiversity. Marine fisheries resources are distributed along the country's extensive 8,118 km coastline, covering an Exclusive Economic Zone (EEZ) of 2.02 million square kilometers and a continental shelf of 0.53 million square kilometers. The inland fisheries sector includes resources such as rivers and canals (1.95 lakh km), floodplain lakes (8.12 lakh hectares), ponds and tanks (24.1 lakh hectares), reservoirs (31.5 lakh hectares), brackish water bodies (12.4 lakh hectares), and saline/alkaline-affected areas (12 lakh hectares). These underutilized and untapped inland resources present immense opportunities for economic growth and livelihood development.

India ranks as the third-largest fish producer in the world, with continuous and sustained growth in fish production since independence. Annual fish production rose from 0.75 million tonnes in 1950-51 to 14.16 million tonnes in 2019-20, reflecting an average annual growth rate of about 8%. Of this total, 74% originates from inland fisheries, while the remaining 26% comes from marine capture fisheries. The total fisheries potential of India is estimated at 22.31 million metric tonnes (2018), with marine fisheries accounting for approximately 5.31 million metric tonnes and inland fisheries contributing 17 million metric tonnes.

1.2. Socioeconomic Conditions of Fisher Communities

Despite the economic significance of the fisheries sector, many marginalized fishers continue to live in poverty, facing multiple socio-economic challenges. Nearly 80% of traditional fishers are illiterate and depend solely on fishing as their primary livelihood. Their daily routine involves venturing into the sea early in the morning and returning by mid-morning. The fish catch is uncertain—some days they return with a good haul, while on other days, they catch little to nothing.
Women in fishing families often take the fish to market for sale, while in some villages, fish are sold through an auction system within the fishing community itself. The youth in fishing communities also rely primarily on fishing. They go out to sea in the morning and, after returning by 11 AM, many work in nearby establishments as unskilled laborers. Women, apart from selling fish, often take up housekeeping and other informal jobs to support their families. Children attend local schools while assisting their families with household responsibilities.

The majority of marginalized fishers struggle with low incomes, preventing them from providing quality education to their children. Many families are burdened by debt, borrowing from banks or local moneylenders. Due to financial constraints, malnutrition is widespread among women and children, resulting in various health issues. Many fishers also feel that existing fisheries policies primarily benefit mechanized vessel operators, with limited government support reaching traditional and small-scale fishers.

1.3. Key Challenges Facing the Fisheries Sector

In recent years, declining fish stocks have posed a major challenge to fishers. Overexploitation by mechanized trawlers, industrial pollution, coastal development, climate change, and the use of inappropriate fishing gear have significantly depleted fishery resources. Traditionally, marginalized fishers operate within 5 nautical miles of the shore, conducting one-day fishing trips. However, with the decline in nearshore fish populations, they are now forced to venture more than 10 nautical miles offshore, increasing both financial risks and physical dangers.
Long-distance fishing requires higher investment in fuel and crew wages. If the fishers secure a good catch, they can manage their daily expenses, but if they return with little or no catch, they struggle to afford basic necessities. Many fishers who rely on hook-and-line fishing have lost access to their native fishing grounds due to environmental changes. The 2014 tsunami significantly altered seabed structures, covering traditional fishing grounds with sand and rock, reducing fish stock availability. Previously, these areas had continuous fish populations, supported by barnacle-covered rocky surfaces that created favorable habitats for marine life. However, after the tsunami, these productive fishing zones disappeared, forcing fishers to venture farther out to sea.

1.4. Environmental and Industrial Threats to Coastal Fisheries

Coastal pollution and industrial expansion have further worsened the challenges faced by fishers. The construction of mega ports, desalination plants, power plants, resorts, and real estate projects has disrupted marine and coastal ecosystems. The expansion of industries along the coast has led to habitat destruction, water contamination, and a decline in fish stocks. Additionally, industrial effluents and untreated sewage discharge into the sea have adversely affected marine biodiversity, impacting traditional fishing grounds.

The overexploitation of fishery resources through unsustainable practices, including the use of inappropriate fishing crafts and gear, has further aggravated the depletion of marine stocks. Small-scale fishers, who rely on traditional methods, find themselves at a severe disadvantage as large-scale mechanized trawlers dominate the industry.

2. The Need for Inclusive and Sustainable Fisheries Management

To address these challenges, a comprehensive and inclusive approach to fisheries management is essential. Sustainable fisheries policies must prioritize the needs of marginalized fishers while ensuring resource conservation. Greater financial support, better access to credit, and skill development programs should be introduced to empower fishing communities.
Additionally, policies must actively promote the participation of women, youth, and other marginalized groups in fisheries management. Inclusive decision-making processes that recognize the traditional knowledge of fishers can help create more effective and sustainable conservation strategies.

The conservation of marine protected areas (MPAs) and broader coastal landscapes must also be strengthened. Stricter regulations on industrial pollution and coastal development activities are necessary to protect marine biodiversity. Alternative livelihood opportunities, such as eco-tourism and aquaculture, can be promoted to reduce dependence on capture fisheries while ensuring economic sustainability for fishers.

By addressing these environmental, economic, and social challenges, India can create a more resilient and sustainable fisheries sector—one that not only ensures the well-being of fishers but also preserves marine ecosystems for future generations.

3. Assessing the Theory of Change for CMCA and the Six Areas of Potential Engagement

The proposed Theory of Change for Coastal and Marine Conservation Areas (CMCA) and the six areas of potential engagement outlined in Attachment 1 provide an adequate and feasible framework to address the challenges associated with coastal and marine conservation. These strategies emphasize a multi-stakeholder approach, integrating traditional knowledge, policy enforcement, capacity building, and sustainable financial models to ensure long-term conservation success.

3.1. Strengthening the Management of Marine Protected Areas (MPAs) and Conservation of Endangered, Threatened, and Protected (ETP) Species

Justification:

Traditional fishing communities play a crucial role in managing and maintaining their fishing grounds within 5 nautical miles to safeguard coastal biodiversity. As part of their fishing rights, they actively contribute to marine conservation by preserving seashores, coastal vegetation, mangrove ecosystems, estuaries, and sea turtle nesting sites. Additionally, they engage in beach restoration and combat plastic pollution by developing community-based biocultural protocols, implementing customary law practices to ensure social responsibility toward environmental protection.

Non-Governmental Organizations (NGOs) play a significant role in capacity building, providing training in coastal biodiversity conservation and promoting the sustainable use of marine resources.
Marine Protected Areas (MPAs) serve as the primary policy and legal instrument available to mitigate multiple threats to marine biodiversity, including overfishing, habitat destruction, and resource exploitation. MPAs facilitate the conservation of ecologically significant rare and endangered species while functioning as breeding and nursery grounds, ensuring continuous fish stock replenishment. Furthermore, MPAs contribute to coastal protection by buffering against storms and waves, reducing excess nutrients and pollutants in marine waters, and maintaining habitat integrity.

Additionally, MPAs promote sustainable tourism and recreational activities, generating alternative income sources for fishing communities while preserving cultural heritage. They also play a crucial role in coral

reef and seagrass restoration, mitigating coastal erosion, and enhancing marine biodiversity. The ecosystem services provided by MPAs—such as fisheries development, coastal protection, tourism, and recreation—are indispensable for human well-being and environmental sustainability.

3.2. Enhancing the Conservation, Restoration, and Sustainable Management of Coastal Areas and Seascapes

Industrial pollution, unchecked coastal development, plastic waste accumulation, oil spills, and the establishment of large-scale coastal industries—including desalination plants, power plants, resorts, and real estate projects—are major contributors to the depletion of fishery resources. These environmental threats have significantly impacted the livelihoods of fishing communities, necessitating immediate intervention.

Strict enforcement of fisheries laws and policies is essential to restore marine resources, protect biodiversity, and maintain coastal ecosystems. Furthermore, all stakeholders, including fishing communities, should receive training in coastal resource management principles to ensure regular monitoring of marine biodiversity. Establishing fisheries management committees at the block, taluk, and district levels would help implement sustainable fishing practices and ensure the responsible use of marine resources.

3.3. Increasing the Resilience of Coastal Communities

Enhancing climate resilience is critical for safeguarding coastal communities that depend on fisheries for their livelihood. These communities are already vulnerable to multiple stressors, including marine pollution, habitat degradation, overfishing, and harmful fishing practices. Climate change, ocean acidification, and increasing climate variability further threaten fisheries resources and coastal livelihoods.

Implementing climate adaptation measures, promoting sustainable fishing practices, and developing alternative income-generating activities can help build resilience within these communities. Integrating disaster preparedness and risk reduction strategies will further minimize vulnerabilities and ensure long-term sustainability.

3.4. Expanding Knowledge, Data Generation, and Information Sharing for Sustainable Marine Ecosystem Management

Traditional fishing communities possess vast indigenous knowledge and time-tested conservation practices that contribute to the sustainable use of marine biodiversity. This knowledge must be systematically documented through a **Community Knowledge Register** using the **People's Biodiversity Register (PBR)** as a tool, with technical guidance from the **National Biodiversity Authority (NBA).**

Advancing digital infrastructure, including IT software, mobile applications, and management information systems (MIS), will facilitate data generation and ensure easy access to critical information. By leveraging technology, coastal and marine ecosystem management can be significantly improved, enabling informed decision-making and effective resource governance.

3.5. Enhancing Opportunities and Leadership Roles for Women and Youth in Coastal Communities

Empowering women and youth through leadership training provides them with opportunities to take active roles in fisheries development, co-management of marine resources, and conservation initiatives. Capacity-building programs focused on sustainable fishing practices, resource management, market strategies, behavioral change, and livelihood development will equip them with the necessary skills to contribute meaningfully to the sector.
By fostering inclusive participation, women and youth can play a key role in ensuring the sustainability of coastal ecosystems while enhancing their own socio-economic well-being.

3.6. Strengthening Sustainable Financing Models for Effective Conservation

Fishing communities must be well-informed about government schemes, financial aid programs, and banking facilities that support their livelihoods. Access to credit and financial literacy programs will enable them to engage in sustainable fishing activities while ensuring long-term income stability.

Encouraging a culture of financial savings and establishing community-based reserve funds will help fishers manage unforeseen challenges, such as natural disasters, without disrupting their fishing operations.

Additionally, training programs on financial risk management, disaster preparedness, and mitigation strategies will enhance economic resilience and contribute to sustainable coastal biodiversity conservation.

The six proposed areas of engagement provide a comprehensive, realistic, and feasible approach to addressing the challenges of coastal and marine conservation in India. By integrating traditional knowledge with modern scientific approaches, enforcing environmental policies, promoting inclusive community participation, and strengthening financial sustainability, India can achieve long-term conservation success. This holistic framework ensures that marine biodiversity is preserved while simultaneously improving the socio-economic conditions of coastal communities.

4. Key Stakeholders for Coastal and Marine Conservation and Strategies for Enhanced Coordination

To ensure effective coastal and marine conservation in India, National and International organizations such as United Nations Development Organizations, United Nations Environment Programme, Food and Agriculture Organisation, European Commission, GIZ, UNAID, USAID and Indian Government and other likeminded international and inter-Governmental agencies must engage with a diverse range of stakeholders at the national, state, and grassroots levels. These stakeholders play critical roles in fisheries management, environmental protection, policy implementation, and community-based conservation. Effective coordination and collaboration among them are essential to achieving sustainable conservation outcomes.

Key Stakeholders

4.1. Grassroots and Community-Level Stakeholders

a) **Fishing Community** – The primary stakeholders who directly depend on coastal and marine resources for their livelihoods. Their participation is crucial for implementing sustainable fishing practices and community-led conservation initiatives.
b) **Fisher Women** – Women play a vital role in fish processing, vending, and marine resource conservation. Their inclusion ensures a gender-balanced approach to fisheries management.
c) **Fishermen Village Panchayats** – Local governance bodies responsible for decision-making at the community level, helping to regulate fishing practices and promote conservation awareness.
d) **Civil Society Organizations (CSOs)** – Non-governmental organizations (NGOs) working on environmental conservation, livelihood support, and policy advocacy for marginalized fishing communities.
e) **Mechanized Trawlers Association** – Representing large-scale fishers who operate mechanized vessels, their engagement is necessary to regulate fishing pressure and promote responsible fishing practices.

4.2. National and International Agencies

a) **Ministry of Environment, Forest, and Climate Change (MoEFCC)** – Responsible for environmental clearances, regulatory linkages, and policy formulation for marine conservation.
b) **Ministry of Fisheries, Government of India** – Oversees fisheries governance, ensuring the implementation of sustainable fishing policies and programs.
c) **Central Marine Fisheries Research Institute (CMFRI)** – Provides technical guidance on fisheries management, stock assessments, and conservation strategies.
d) **Central Institute of Brackishwater Aquaculture (CIBA)** – Offers expertise on sustainable aquaculture practices, particularly for brackish water fisheries.
e) **Marine Products Export Development Authority (MPEDA)** – Supports post-harvest practices and ensures quality control for marine product exports.
f) **Central Institute of Fisheries Technology (CIFT)** – Provides training in fishing methods, responsible fishing practices, and skill development.
g) **State Fisheries Departments** – Implement fisheries policies at the state level and provide support to fishing communities.
h) **State Forest and Environment Departments** – Oversee coastal and marine biodiversity conservation, including mangrove and wetland protection.
i) **Ministry of Shipping Corporation and Indian Coast Guard** – Play a key role in enforcing marine safety regulations, preventing illegal fishing, and managing marine pollution.

4.3. International and Financial Institutions

a) **United Nations Development Programme (UNDP), including OP7 GEF UNDP SGP TERI Delhi** – Provides funding, policy support, and capacity-building initiatives for sustainable fisheries and conservation projects.
b) **Food and Agriculture Organization (FAO)** – Offers technical guidance on global best practices in fisheries management and ecosystem conservation.
c) **Asian Development Bank (ADB) and World Bank** – Provide financial assistance and policy support for large-scale marine conservation and livelihood development programs.
d) **Independent Expert Consultants** – Researchers and subject-matter specialists who provide insights on sustainable fisheries, climate resilience, and biodiversity conservation.

5. Strategies for Strengthening Stakeholder Coordination and Collaboration

To enhance the effectiveness of coastal and marine conservation efforts, the following strategies should be implemented to improve coordination among these stakeholders:

5.1. Establishing Multi-Stakeholder Committees

a) Form a **National Coastal and Marine Conservation Task Force** comprising representatives from government bodies, research institutions, CSOs, and fishing communities to streamline decision-making and policy execution.
b) Set up **State-Level Fisheries and Marine Conservation Councils** to ensure state-specific policy implementation and feedback mechanisms.

5.2. Enhancing Knowledge Sharing and Capacity Building

a) Develop an **Integrated Marine Conservation Database** to facilitate data sharing on fish stocks, marine biodiversity, and conservation programs among research institutions, policymakers, and fishing communities.
b) Conduct **regular training programs** for fishers on sustainable fishing practices, marine biodiversity conservation, and financial literacy.

5.3. Strengthening Community Participation and Co-Management.

a) Implement **Community-Based Marine Protected Area (MPA) Management Plans**, engaging local fishers in conservation and enforcement efforts.
b) Encourage **women's cooperatives and youth groups** to participate in marine resource management, fostering inclusive decision-making.

5.4. Promoting Sustainable Financing and Incentive Mechanisms

a) Develop **co-financing models** where government funding is supplemented by private sector investment and international grants for conservation projects.
b) Introduce **financial incentives** (e.g., tax benefits, grants) for sustainable fishing practices and responsible aquaculture initiatives.

5.5. Strengthening Policy Implementation and Enforcement

a) Ensure **strict enforcement of environmental laws** related to coastal pollution, illegal fishing, and habitat destruction.
b) Enhance collaboration between the **Indian Coast Guard, fisheries departments, and local communities** to monitor illegal activities and protect marine biodiversity.

Effective coordination among stakeholders at the national, state, and grassroots levels is essential to achieving long-term coastal and marine conservation in India. By fostering multi-stakeholder partnerships, strengthening data-sharing mechanisms, promoting inclusive community participation, and ensuring sustainable financing, United Nations Development Organizations, United Nations Environment Programme, Food and Agriculture Organisation, European Commission, GIZ, UNAID, USAID and Indian Government and other likeminded international and inter-Governmental agencies can support a holistic and impactful approach to preserving marine ecosystems while securing the livelihoods of coastal communities.

6. Promising Innovations for Joint Economic Prosperity in Fishing and Non-Fishing Coastal Communities

6.1. Marine Fisheries Sector and the Indian Economy

The marine fisheries sub-sector contributes approximately 1% to India's national Gross Domestic Product (GDP), yet it plays a vital role in the coastal rural economy. It provides income, employment, and food security to an estimated 3.52 million people across India's 8,118 km coastline, spanning eight maritime states and two union territories.[7]

6.2. National Fisheries Policy: Sustainable Fisheries and Marine Biodiversity Conservation

6.3. Vision: *To establish a healthy and vibrant fisheries sector that meets the needs of present and future generations.*
6.4. Mission: *To ensure the sustainability of marine resources while achieving social and economic goals for fishers and fish farmers. The National Fisheries Policy aims to guide the coordination and management of the fisheries sector over the next decade.*

6.5. Key Areas for Immediate Intervention

a) **Promoting deep-sea fishing and Areas Beyond National Jurisdiction (ABNJ):** Encourage the responsible use of technology and capacity-building programs to tap into underutilized marine resources, particularly benefiting artisanal fishers. Investments should be made in developing robust harvest and post-harvest facilities.

b) **Optimizing fishing efforts and stock management:** Implement management plans to rebuild degraded fish stocks and maintain sustainable fishing practices.

c) **Developing conservation measures:** Introduce species-specific and zonal/area-specific management plans through consultative processes. A holistic strategy for resource utilization in the Exclusive Economic Zone (EEZ) is essential.
d) **Encouraging Ecosystem Approach to Fisheries Management (EAFM) and co-management approaches** to enhance sustainability and community participation.
e) **Reserving areas for non-mechanized fishing boat operators** under the Marine Fishing Regulation Acts (MFRAs) to support small-scale fishers and preserve traditional fishing practices.
f) **Leveraging IT and digital technologies** for efficient knowledge management across the fisheries sector.
g) **Ensuring fisher safety and national security** by strengthening protocols for deep-sea and transboundary fishing activities.[8]

6.6. Post-Harvest Management & Trade

a) A sustainable food value chain (FVC) includes all stakeholders engaged in production and value-adding processes to ensure high-quality food products. Key attributes of a sustainable FVC include:
b) **Economic sustainability** – Profitability at all stages of production and distribution.
c) **Social sustainability** – Equitable benefits for all stakeholders, particularly marginalized communities.
d) **Environmental sustainability** – Minimal or positive ecological impact.

At present, significant post-harvest losses occur in both the marine and inland fisheries sectors. Reducing these losses is critical to improving food security, ensuring additional fish availability, and maintaining safety standards for consumers. Investment in cold chain infrastructure, improved storage, and value-added processing will help minimize losses and enhance market opportunities.

7. Recommendations for Enhancing Coastal and Marine Conservation

To improve coastal and marine conservation both inside and outside Marine Protected Areas (MPAs), a comprehensive approach must be adopted that takes into account India's economic, political, gender, and social realities. The following key areas require immediate intervention:

7.1. Regular Biodiversity Monitoring

a) Conduct systematic monitoring of critical environmental parameters such as sea surface temperature, air temperature, salinity, ocean acidification (pH), precipitation, ocean currents, and sea level rise.

[7] http://eprints.cmfri.org.in/15861/1/Indian%20Fisheries%20Outlook_2022_Shyam%20Salim.pdf

[8] https://dof.gov.in/sites/default/files/2020-12/Policy_0.pdf

b) Government agencies should implement precautionary measures based on data insights to safeguard coastal biodiversity and marine ecosystems.

7.2. Promoting Science, Innovation, and Technology

a) Advance research and technological innovations to enhance marine fisheries resources and the conservation of coral reefs, seagrass, endangered species, and mangrove ecosystems.
b) Support studies to understand climate change impacts on fisheries and aquaculture.
c) Pilot adaptation measures for fishers and fish farmers to cope with climate-related changes and associated natural events.

7.3. Sustainable Energy and Infrastructure Development

a) Encourage the use of solar energy in fishing boats, fisheries infrastructure, and aquaculture operations.
b) Ensure the safety and security of fishers, particularly those engaging in deep-sea fishing.
c) Develop climate-resilient technologies in partnership with government agencies and the private sector, including open-sea cage culture, artificial reef deployment, and seaweed farming.

7.4. Alignment with National and Global Conservation Goals

a) Integrate conservation efforts with national policies such as the National Action Plan on Climate Change, National Biodiversity Action Plan, and National Adaptation Fund for Climate Change.
b) Align strategies with the United Nations Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land).

7.5. Sustainable and Responsible Fisheries Management

a) Promote deep-sea fishing and responsible exploitation of under-utilized resources in Areas Beyond National Jurisdiction (ABNJ).
b) Optimize fishing efforts and implement management plans to restore degraded fish stocks.
c) Develop conservation measures, including species-specific and area-specific management plans through consultative processes.
d) Encourage coastal states and union territories (UTs) to designate more areas for non-mechanized fishing boat operators under the Marine Fishing Regulation Acts (MFRAs).
e) Promote the adoption of Ecosystem Approach to Fisheries Management (EAFM) and co-management frameworks.

7.6. Gender Inclusion and Community Engagement

a) Ensure the active participation of women in fisheries development, including decision-making processes.
b) Promote women-led initiatives in seaweed farming, oyster and crab cultivation, eco-tourism, and the marketing of fish and fish products to enhance their sustainable livelihoods.

7.7. Knowledge Management and Capacity Building

a) Facilitate knowledge sharing across the marine fisheries sector through the use of advanced IT technologies.
b) Provide training on climate-smart technologies for fishers and coastal communities.
c) Develop and strengthen Foreign Direct Investment (FDI) in deep-sea fishing and promote access to global markets.

7.8. Ecosystem Conservation and Protection

a) Protect and restore key coastal ecosystems, including seaweed beds, mangroves, salt

marshes, coral reefs, estuaries, pelagic, and benthic habitats to support sustainable fisheries.

b) Implement public-private partnerships to enhance fisheries research, development, capacity building, advocacy, and policy reforms.

7.9. Inter-Governmental and Institutional Collaboration

a) Foster stronger collaboration between national and state agencies, research institutions, civil society organizations, and international bodies.

b) Develop inter- and intra-governmental partnerships to coordinate conservation efforts effectively.

By implementing these strategic interventions, India can strengthen its coastal and marine conservation efforts, ensuring ecological sustainability, economic resilience, and social inclusivity in the fisheries sector.

8. Conclusion

The sustainable management of India's coastal and marine resources is crucial for the long-term prosperity of both fishing and non-fishing coastal communities. The **National Fisheries Policy** provides a strategic framework to balance economic growth with ecological conservation, ensuring that fisheries remain a vital contributor to the national economy while protecting marine biodiversity.

Key interventions, such as **deep-sea fishing, habitat conservation, and responsible resource utilization**, will help rebuild fish stocks and mitigate the adverse effects of climate change. Strengthening **marine protected areas (MPAs), promoting climate-resilient technologies, and encouraging sustainable fishing practices** will ensure long-term ecological and economic benefits.

The role of **post-harvest management and trade** is equally important in reducing losses and improving food security. By enhancing cold chain infrastructure, processing techniques, and value chain integration, India can optimize its fisheries output while ensuring fair economic returns for fishers.

Collaboration among key stakeholders—including the government, research institutions, private sector, NGOs, and local fishing communities—will be essential for effective policy implementation. Encouraging gender inclusion, particularly in decision-making and livelihood diversification, will strengthen the resilience of coastal communities.

Finally, fostering **public-private partnerships, leveraging digital technologies for data-driven decision-making, and securing sustainable financing models** will be instrumental in achieving long-term conservation goals. By integrating ecological sustainability with economic prosperity, India can lead the way in responsible marine resource management while improving the livelihoods of millions dependent on the fisheries sector.

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ENRICHMENT OF TRADITIONAL CHUTNEY POWDER USING ANCHOVIES

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Abstract:
Can convenient ready to eat foods contribute to improving the quality of home diets?
The research study aims to demonstrate the preparation of an Instant Ready to Eat Chutney Powder with Anchovy. The Nethili fish called Anchovies are nutrient dense, small oily fish which is very popular in South India (Tamil Nadu and Kerala) and other countries like UK, Italy, America, Indonesia, Malaysia and provides major health benefits. They are best known as a source of omega-3 fatty acids, which promote brain and heart health. Most of the Indian population in India and around the world are in the habit of consuming idly and Parupu podi (Dhal Powder). Adding proportional quantity of Anchovies in Parupu podi is a value addition, for the non-vegetarians consuming this product on a daily basis. Moreover, the other existing ingredients in the Idly chutney powder with anchovy will further supplement human health. In this study the RTE powder was formulated with different proportions of dehydrated Anchovy fish powder and was found highly acceptable when subjected to sensory evaluation for its acceptance. The proximate composition and omega fatty acid content of the formulated powder was analysed. An E-survey was also initiated to gather information on the preference of consumers about their likings for non-vegetarian flavours added to RTE powders, the survey results revealed high acceptance.

Key words
Nutrient enrichment, Anchovy, Instant Ready to eat product.

CHAPTER – I
INTRODUCTION INTRODUCTION
A culinary innovation, convenience foods are regarded as a socially, economically,

and culturally acceptable, routine consumption foods.
De Boer et al (2004) described convenience foods as the food items that are fully prepared or partially prepared. In these food items the processing skills, preparation time required for the food and energy inputs needed has already been done by the food processor.
A research of future food trend from Annals. Food Science and Technology (Mehmeti, G. and Xhoxhi, 0., 2014) conveyed that convenience and nutrition are among the top influencers in the food market. Peura-Kapanen et al., (2017) survey, although it does not reach the older people, it is agreeable that older people can actually accept Ready-to-Eat foods if the taste meets their preference, and if the products take healthiness into account
(Solanki, 2017) has researched and stated that there are around 80% of the people who consume ready-to-eat food and this market has only taken an upward trend in the recent years.
Convenience food industry has shown a rapid growth in India in the last few years. These foods are saviour for busy and working people. Urbanisation and the changing lifestyle have a huge role in increasing the demand of such food items. They are gaining immense popularity in the food industry, global food market and among the food scientists. In the past few years convenience food has shown a remarkable growth in the food market (Silky Verma and Gurjeet Kaur Chawla,2020).

Today, consumers look forward to healthy foods, variety and taste, foods that are easy to consume replacing the traditional cooking pattern. Therefore, the food processors and researchers are developing more healthy convenience food products

These factors are the major drivers for undertaking this study on preparation of a RTE instant chutney powder with anchovies

CHUTNEY POWDER AN OVERVIEW:

In the recent days the ready to eat foods plays a major role in youngster's lives, such as students who stay away from their homes. The eating pattern of youngsters has changed such a way that rather than having a healthy meal they prefer one tasty meal that is not much time consuming and easy to make and have it. This study is undertaken not only to make eating easy but also healthy and nutritious

Paruppu podi also called as Idli podi or chutney podi in many places in South India is a famous ready to eat product that is made traditionally and consumed over decades in our country. Basically this RTE powder is made of thoor dal and urad dal predominately and spiced together with masala mix, it is consumed with idli , dosa , rice , ect with some oil or ghee. The core of the recipe remains the same across Southern India - urad dal, chana dal and red chillies. But it is the minor variations in some of the other ingredients that alter the flavour from state to state.

For the past few decades, podi idlis have been the ideal travelling companion. Many travellers in Tamil Nadu and other Southern Indian states would consume their idlis with the powder and oil mixture during a time when the availability of packaged food was restricted.

A non-vegetarian liking to consume this traditional breakfast with fish curry also exists among the Indian population. Hence this research through a survey also includes a questionnaire to determine the likings of consumers on their preference of non-vegetarian twist to this existing chutney powder and the consumption pattern of non-vegetarian foods in their day to day lives.

Anchovy fish have a whole different fan base among all the fishes that is available fishes in the market because of it distinct flavour and aroma. Dried Anchovy is the famous among all other formats that are available.

CONSUMERS FOOD PREFERENCE IN THIS CENTURY

RTE foods are gaining popularity because of the abundance of newly introduced, low-priced and simple-to-use goods on the market. Most people prefer to buy RTE foods since they do not have to perform any arduous preparation work, such as grinding by hand or dredging for ingredients. RTE foods are both time- and money-efficient due to their pre-prepared nature. Because of the time, effort, and money it saves its users, its popularity has grown (Sharma, 2022)

Demographic factors did not have a big influence on RTE product purchases in the majority of Asian nations. Yet, individuals appeared to view RTE product outlets favourably on the whole. Customers think RTE goods can speed up food preparation. Customers mostly cited convenience as the reason they kept buying RTE items. Convenient stores appeal to young consumers as enhancing their well-being, which may mean 'convenience' of product is not a stand-alone value but must support health.

In recent days the ready to eat food is manufactured in such a way it promotes health benefits and health claims to have a healthier lifestyle in a minimal cost. Snack and short bites foods are the trend now and used widely now a days. The snack foods market is currently demanding healthier products Ramona J, E.M et al., 2016.

ANCHOVIES

Anchovies are small sized oily fish that is abundantly available in the local and high markets in South India, very popular because of its unique odour and taste.

The Nethili fish called Anchovies are nutrient dense, small oily fish which is very popular in South India (Tamil Nadu and Kerala) and other countries like UK, Italy, America, Indonesia, Malaysia and provides major health benefits.

NUTRITIONAL FACTS:

Anchovies are highly nutritious food and particularly valuable for providing protein of high quality, better than those of meat and egg and are a suitable medium for microbial spoilage. (Kader, 2005). The problem of spoilage could be solved and the shelf life can be extended by preservation using solar drying techniques. (Relekar, S.S et al., 2014).

Anchovies are rich in omega-3 oils, calcium and iron. The boiled and dried anchovy is a ready-to-eat product, or it can be lightly fried along with spices and consumed. (Gencbay, G. and Turhan, S., 2016).

Anchovy fish is best known for is nutritional compositions; anchovy is added as an value addition in numerous products for improving the health. In a recent research anchovy was added with kimchi to have more effect on heat and withstand against microbes. Characteristics of kimchi added with anchovy sauce from heat and non-heat treatments. (Kang, H.W et al., 2018).

The ever-changing food consumption behaviour of consumers is towards convenient, affordable, nutritional, and tasteful food products, while preserving the traditional aspects of food, and the market for such products is expanding rapidly.With this market for convenience food this study aims to incorporate the already famous Idli podi with Anchovy fish powder.

In this fast moving consumer world people do not eat their breakfast properly as they rush to school, college, work which leads to various health complications. In view of this the researcher aim in this study is to formulate a product that is tasty and enriched with nutrients of anchovies that can be consumed as an accompaniment with breakfast.

In 2020, an estimated 13.3 per cent of the world's food was lost after harvesting and before reaching retail markets. Sustainable development Goal 12 is about ensuring sustainable consumption and production patterns, which is key to sustain the livelihoods of current and future generations. Governments and all citizens should work together to improve resource efficiency, reduce waste and pollution, and shape a new circular economy. (sdgs.un.org ,2022).**SDG goal 12 works towards reducing food wastage .**

This study also adds value to the field of food research, as in many parts of the world, the lack of free access to refrigeration or ice leads to spoilage and deterioration of freshly caught fish increasing food wastage. By reducing the moisture content of the fish through drying we can ensure a stable source of protein that can be transported to communities with limited access to fresh fish. Hence the study is also socially relevant as by drying and incorporating the dried anchovies in widely consumed vehicle like chutney powder we are reducing food waste as well as making a fish source available in unavailable areas and also maximising the utilization of these anchovies.

CHAPTER – II

SCOPE AND OBJECTIVE SCOPE OF STUDY:

- The rising population has made a huge impact on the demand for the packaged food items in the market. Due to their fast and busy lifestyle they try to purchase food items that are convenient to use and saves their time in processing in further. Hence adding value to such convenience foods will benefit the consumers.

OBJECTIVE:

- To conduct an E-survey to gain information on the preference of consumers about their liking for non-vegetarian flavors added to RTE powders.
- To formulate and prepare the product using different proportions of dehydrated Anchovy fish powder.
- To evaluate the sensory properties of the formulated product for its acceptance.
- To determine the nutritional composition of the formulated powder.
- To conduct Shelf life study of the formulated powder.

CHAPTER – III

REVIEW OF LITRATURE

It is increasingly significant to determine the factors that influence consumer behaviour and his/her attitudes regarding healthy foods in order to verify the opportunities for further expansion of this segment. From the consumer point of view, the success of healthy foods relies on a number of inter-relating factors, including the level of concern about general health the belief that it is possible to influence one's own health and awareness and knowledge of foods/ingredients that are supposed to be beneficial. (Azzurra Annunziata,et al., 2009)

ANCHOVIES AN INTRODUCTION:

Anchovies are small pelagic fish start to appear in the catches in late September or early October. The season ends around March/April but schools are said to be spotted until May

Anchovies are one of the important pelagic fish species found in the Indian Ocean,

which can grow up to 20 cm (8 in), and prefer the warmer waters around the world. The limiting factors in the effective utilization of anchovies are their small size, seasonal nature of the fishery forming gluts, sensitive to physical, time and temperature changes. Anchovies are rich in omega-3 oils, calcium and iron. They can be cooked fresh, usually sold packed in salt, tinned in oil, as a paste in jars or tubes, or as a sauce. Anchovy pickled products have been developed using application of different inhibitory factors to achieve a reasonable shelf life at ambient tropical temperature.(Dipty a. shiriskar, G.D, et al., 2010)
A study on length and weight data for 1014 specimen of *Stolephorus indicus* were collected during period from September 2016 to July 2017. The smallest size recorded for the S. indicus was 8.4 cm total length and 4.7 gm weighing, while the largest size was 15.3 cm TL and 28.13 gm and average size of species was 11.7 cm. (Patadiya, D. S., et al 2018).
A research analysed intraspecific diversity of Indian anchovy, *Stolephorus indicus*, a commercially and ecologically important species, using mitochondrial DNA markers so as to derive insights into population structuring and historical demography. Historical demographic analyses indicated signals of demographic and spatial expansion around 125,000 years before present. (Sandhya Sukumaran, et al. 2019).

Anchovies are plankton feeders, mainly zooplankton with copepods, cladocerans, lucifer and fish larvae dominating. Changes in physico-chemical properties of the ecosystem regulate its migration, resulting on the annual and seasonal fluctuations in its fisheries. The northward distribution of the stock in shallow shelf water from October onwards and the southward distribution from March-April onwards are evidently governed by the current patterns during the southwest monsoon and post-monsoon period. This study reports the distributional shift of Stolephorus along southwest coast of India. (Bharti, V., and Jayasankar, J. 2019).
Stolephorus Lacepède, an Indo-Pacific genus of marine and/or brackish water anchovies (Engraulidae), comprises 26 valid species.. (Hata, H., and Motomura, H. 2020).
Anchovy is the highest marine fishery commodity , easy to be obtained in the market and has an affordable price. Anchovy has a potential nutritional value for human health. The recommended amount per serving of crispy anchovies is 20 grams. (Swastawati, F., et al. 2020).

DEHYRATION A PROCESS TO ENHANCE SHELF LIFE AND REDUCE WASTAGE

Research regarding anchovies revealed that the dried end product has a long shelf life, providing a source of protein, vitamins and minerals when the fresh fish themselves may not be available in offseason. (Sankat and Mujiaffar, 2004)

Anchovies are highly nutritious food and particularly valuable for providing protein of high quality, better than those of meat and egg. However, they are the most perishable of all the foods because there are a suitable medium for growth of micro-organisms after death (Kader, 2005).
Production of low cost salted and dried product from anchovy fish (Stolephorus spp.) using traditional technology application of different inhibitory factors to achieve a reasonable shelf life at ambient tropical temperature. Microbial safety, nutrient retention and product quality in terms of flavor and texture after rehydration have been tested. This product has been subjected to storage studies, with respect to product quality and microbial status. It can be kept well for a period of 5 weeks. (Siriskar, D. A,et al., 2013).

The problem of spoilage could be solved and the shelf life can be extended by preservation using solar drying techniques. Sun drying is one of the traditional simple and economical methods employed to preserve fish, particularly small pelagic fish (Relekar, Joshi, Gobe, and Kulkarni, 2014).

Solar drying is an improved method of sun drying. It minimizes or stops some of the limitations of open sun drying (FAO, 1981; Relekar et al., 2014).
Solar drying differs from open sun drying in a structure, often very simple in construction, which is used to enhance effect of the insulation (Yu, Siaw, and Idrus, 1982)
The fish were cooked by different methods (frying, baking and grilling) at two different temperatures (160 °C, 180 °C). Crude ash, crude protein and crude fat contents of cooked fish increased due to rise in dry matter contents. While cooking methods affected mineral content of anchovy, cooking temperature did not affect. After cooking process using three methods, dry matter, ash, fat and protein contents of fish

significantly ($p<0.05$) increased. (Uran, H., and Gokoglu, N. 2014)

Ragasudha, (2023) has developed and evaluated a PV-powered solar-infrared hybrid dryer (SIHD) for the uninterrupted drying of anchovy fish. It consists of a cylindrical drying chamber, infrared (IR) lamp, drying trays, solar PV panel, battery, and a remote monitoring system. A remote data acquisition unit with a controller and sensors was integrated with the SIHD to obtain drying data and maintain desired drying conditions. The moisture of anchovy was reduced from 83.7% to 15.2% in 6.25 h by SHID, while it takes 10.30 h in a solar dryer and 16.20 h in the open sun drying to achieve the moisture content of 15.3% and 15.5% respectively. The maximum drying efficiency of 30.43% and 41.11% was obtained. The dried samples obtained from the solar infrared hybrid dryer received the highest overall acceptability score with superior color and texture. This study helps to understand the new and innovative approach of using solar-IR hybrid technology in the drying process for controlled and efficient drying with scope for large-scale adoption possibilities.

For getting better quality dried fish, it is very essential to use improved method of fish drying.

ANCHOVIES NUTRITIONAL COMPOSITION AND HEALTH BENEFITS.

The anchovy (*Engraulis encrasicolus*) popularity as a commercial fish species is partly due to the particularly rich nutritional profile it boasts, including a high content of essential fatty acids, including polyunsaturated fatty acids (PUFAs) — among which are the omega 3 fatty acids, such as docosahexaenoic acid (DHA) and ecosapentaeonic acid (EPA) — and omega-6 fatty acids, like arachidonic acid (ARA) (Zlatanos and Laskaridis, 2007)

Changes in proximate composition of anchovy were investigated during the catching season from October to March. In addition, stability of anchovy oil depending on storage temperature and time were studied. The anchovy oil stored at 4C was found to be unacceptable for consumption at the end of the 90th day of storage according to peroxide, acid, unsaponifiable matter and thiobarbituric acid values. An identical sample stored at -18C was acceptable for 120 days of storage, but eventually became unacceptable after that. Boran, G., Boran, M., and KaraCAm, H.(2008).

Marine fishes are rich sources of ω- 3 fatty acids especially, Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA). (Aneesh, P. A, et al, 2012).

Fatty acids	Nemipterus japonicas	Rastrelliger kanagurta	Stolephorus commersonii	Thunnus albacores
Saturated Fatty acid (SFA)				
C 12:0	-	0.1	0.77	0.42
C 13:0	0.1	1.52	7.23	1.32
C 14:0	1.21	1.2	6.84	2.13
C 15:0	1.13	0.77	1.35	0.97
C 16:0	23	22.14	41.27	31.61
C 17:0	1.48	1.25	1.49	1.53
C18:0	11.88	10.77	10.75	11.42
Others	1.44	2.18	2.59	1.56
Total SFA	**40.24**	**39.93**	**72.3**	**50.96**
Mono unsaturated fatty acid (MUFA)				
C 16:1, n7	3.4	2.2	6.23	2.95
C 17:1,n7	0.2	0.32	0	0.34
C18:1, n9	14.22	15.06	8.36	13.86
C20:1, n9	-	0.88	-	0.95
C22:1, n9	0.22	0.1	-	0.29
Others	1.47	1.4	-	2.16
Total MUFA	**19.51**	**19.96**	**14.59**	**20.55**
Poly unsaturated fatty acids (PUFA)				
C 18:2, n6	-	0.1	1.93	13
C 18:3, n3	0.66	0.4	1.59	1.37
C 20:2, n6	-	0.7	-	1.02
C 20:3, n6	-	0.2	-	1.13
C 20:4, n6	4.23	2.98	2.06	0.54
C 20:5, n3 [EPA]	**6.56**	**5.2**	**1.66**	**0.43**
C 22:6, n3 [DHA]	**26.55**	**28.52**	**5.87**	**8.3**
Others	1.85	2	-	2.66
Total PUFA	**39.85**	**40.1**	**13.11**	**28.45**

Figure 1 FATTY ACID PROFILE OF ANCHOVIES

Fish plays a major role in human nutrition. In the present study, the ω- 3 polyunsaturated fatty acids composition in common food fishes of Arabian Sea viz. Indian mackerel (Rastrelliger kanagurta), Yellowfin tuna (Thunnus albacares), Commerson's anchovy (Stolephorus commersonii) and Japanese thread fin bream (Nemipterus japonicas) are compared. Marine fishes are rich sources of ω- 3 fatty acids especially, Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA). The EPA content, of Commerson's anchovy was 1.66% and the DHA content of Commerson's anchovy was (5.87%) The disease such as asthma, diabetes, psoriasis, thyrotoxicosis, multiple sclerosis etc. can also be moderated by ω-3 fatty acids. A person can expect good health if he or she consumes 0.5 -1g of ω–3 PUFA/day. Hence, regular consumption of these Indian food fishes may alleviate diseases/disorders related to malnutrition and aging. (Aneesh.P.A.2012).

The anchovy the low value fish demonstrated a high nutrient complement and hence can be an effective nutrient supplement for daily food. The higher essential amino acids, higher content of PUFA and MUFA and low sodium and high potassium and calcium could make a better nutrient for the consumers at a cheaper rate. India with its 8,118 km long vast coastal line

has tremendous potential in terms of marine food resources. (Sankar, T. V.r,et al, 2013).

EPA and DHA are forming compounds of Omega 3 anchovy (*Stolephorus Sp.*) oil concentrate. Content analysis results of anchovy fatty acid 1% using spectrophotometer GC-MS, EPA identified at minute 14,43 with similarity index 27,5 %; and DHA identified at minute 15,50 with similarity index42,6 %. Both of these compounds have m/e value peak base 79. Omega 3 derived from anchovy (*Stolephorus Sp.*) insulation oil shows a high similarity index with omega 3 standards (figuredas results of spectrophotometer GC-MS). The omega 3 content, especially EPA and DHA of anchovy obtained from Sinjai Regency (Sulawesi Selatan) has significant similarities with omega 3 of anchovy as published by previous researchers which states that the anchovy *(Stolephorus Sp*.) is a cheap local fishery products and very easy to find. Anchovy classified as oily fish contains high category ofomega-3 fatty acids. (Mattimu,(2016).

Nanoparticle preparation can increase the bioavailability of anchovy protein. This study aims to optimize and characterize anchovy protein concentrate nanoparticle based on volume comparison of chitosan-TPP (Tripolyphosphate) matrix in forming the size of anchovy protein concentrate nanoparticle with ionic gelation method. The results showed that ionic cross-interaction between chitosan positive charge and TPP negative charge occurred perfectly in trapping anchovy protein concentrate. This was indicated by the value of the encapsulation efficiency obtained was more 95%. (SAPIUN, Z. et al, 2020).

Macrominerals contained in crispy anchovies were phosphor, sulfur, calcium, and potassium. (Swastawati, F., et al, 2020).

Providing information about the effectiveness of anchovy extract (*Stolephorus sp*), on the condition of the oral cavity of children, the author wants to compare the level of effectiveness of a natural ingredient *stolephorus sp* an antibacterial agent in the oral cavity of children. Anchovy (*Stolephorus Sp*) extract has effectiveness as an antibacterial against the growth of streptococcus mutans, with the amount of fluoride 15,416-24,914 ppm, which in the oven has the potential as a source of natural fluoride. So, the effectiveness of anchovy, will provide enormous benefits for children during their growth and development. (Achmad., 2022).

The proximate composition of small pelagic fish such as anchovies and sardines depends on the fishing season. Anchovies are composed of 65.9–77.9% water, 12.8–19.8% protein, 1.81–15.3% fat and 1.5–2.3% ash. Proximate composition and amino acid composition of anchovies are presented in this review in addition to their application in food products. It is highlighted that anchovies from different species contain different values of proximate composition and amino acids. (Kari, N. M., Ahmad, F., and Ayub, M. N. A. 2022).

Chemical composition (ww) of the raw anchovy fish flesh (Mohamed Abdellhady Ibrahim et al.,2022)

Table I

Item	Chemical composition;			
	Moisture %	Protein%	Lipid%	Ash%
Anchovy flesh	72.10 ± 0.12	18.23 ± 0.02	5.20 ± 0.27	4.36 ± 0.04

Anchovies are rich in macronutrients and micronutrients such as protein, carbohydrate, fat and amino acids. In addition, anchovy is composed of well-balanced amino acid compositions containing eight essential amino acids and eight non-essential amino acids. The nutritive value of anchovies has become the reason for numerous food applications.(Kari, N. M,et al., 2022).

REVIEW ON EXISTING VALUE ADDED PRODUCTS USING ANCHOVIES

The processing of fish meat into value added snack as seafood cookies is an innovative attempt at providing good nutritive value to the consumers. Indian anchovy is an excellent fortifier in cookies as well as other bakery products and this will lead the way to the fishery by-product industries. The shelf life of the seafood cookies is 20 days in the ambient temperature (27oC). (Jeyanth Allwin, S. I,et al., 2018).

Anchovy fish is best known for is nutritional compositions, anchovy is added as an value addition in numerous products for improving the health,in a recent research anchovy was added with kimchi to have more effect on heat and withstand against microbes. Characteristics of kimchi added with anchovy sauce from heat and non-heat treatments. Kang, H.W et al., 2018.

The substitution of kaopi using anchovy flour affects the nutritional value. In addition, the best kasuami/kasoami based on the organoleptic test were obtained in T5

treatment. The determination of the best treatment was done based on Duncan test and organoleptic test. Meanwhile, the results of the chemical components analysis of kasuami/kasoami are carried out through the weighting method. (Mamangkey, J. 2022).

The aim of this study was to determine the proximate composition (lipid, crude protein, crude ash and moisture) of three different fish wastes [trout (*Onchoryncus mykiss*), anchovy *(Engraulis encrasicolus)*, In the study, it was determined that the chemical composition of fish wastes may vary according to the type of fish and months during catching season (Korkmaz, K., and Tokur, B. 2019).

An attempt was undertaken to evaluate the shelf-life of Ready To Eat (fish cutlet) of anchovies (Stolephorus commersonii). Fish cutlet was prepared by following standardized recipe and it was subjected to proximate composition. core of sensory attributes like appearance, colour, taste, texture and odour were assessed and the mean value for overall acceptability score (OAS) was determined. It could be observed that overall mean acceptability score reduced significantly with increase of storage period. The ideal shelf life for storing anchovies fish cutlet at frozen storage condition was found to be 18 days. (Bharathipriya,et al., 2019).

Anchovy oil was encapsulated into microcapsule powder creating multi-core structure using a two-step microencapsulation method using gelatin-SHMP complex as the shell material. The inner and the outer shells of the microcapsule were created separately during the microencapsulation. The ATR-FTIR analysis indicated that there was no oxidation or degradation of oil in the solid microcapsules during the microencapsulation and spray drying processes. (Wang, B.,et al., 2019).

Anchovy (*Engraulis japonicus*), a small, low-valued, marine fish, and soybean meal (*Glycine max*), a by-product of soybean oil extraction, are both abundant protein resources (approximately 65 and 46 g per 100 g dry weight, respectively). In this study, water-soluble protein powder from anchovy and soybean meal was obtained by two processes, anchovy endogenous enzymatic hydrolysis (stage 1), and solid-state fermentation of anchovy hydrolysis residue and soybean meal (stage 2). The product obtained in this study contained abundant peptides, and the amino acid composition was reason- able. This product could be used as food or feed additive. This work provides a novel technique for the advanced utilization of low-value resources. (Li, L.,et al., 2019).

A Research investigate selected chemical, technical, and economic aspects of the production of fish oil rich in polyunsaturated omega-3 fatty acids from anchovy filleting leftovers using *d*-limonene as the extraction solvent at ambient temperature and pressure.Extraction of anchovy fish oil rich in omega-3 lipids from anchovy discards using orange oil-derived *d*-limonene is advantageous and economically and technically feasible. The capital investment in the low-energy extraction setup, including the bio-based solvent and the solar air dryer, is relatively modest, and the operational costs are mostly due to labor and electricity to separate the oil from the agro solvent. (Ciriminna, R., 2019).

Fish protein isolate (FPI) extracted from whole ponyfish (Equulites klunzingeri) by pH-shift process was used to microencapsulate raw anchovy oil (Engraulis encrasicolus) by spray drying. Since the use of FPI gave good results as a wall material for microencapsulation of fish oil, it can be potentially used as a nutraceutical agent in food systems.(Özyurt, G,et al.,2020).

Functional and bioactive properties of fish proteins have gained importance day by day, and therefore, it is wondered how these sources can be used more effectively. The method used in the study could contribute to the use of microencapsulated anchovy oil with fish protein isolate as a nutraceutical product in food systems. (Özyurt, G,et al., 2020).

Surface Methodology (RSM) was applied to optimize the processing of an instant rice-based cereal enriched with anchovy powder. Viscosity, consistency, and cohesiveness of the reconstitute cereal were also evaluated. The study shows a complex relationship between drying temperature, drum speed, and slurry solids concentration, with respect to their individual as well as combined effect on product characteristics of brown rice-anchovy powder instant cereal. (Akonor, P. T.,J,at al., 2021).

This study aimed to determine effect of concentration addition of chitosan on quality of water content, protein, fat, carbohydrates, organoleptic and Total Plate Count (TPC) test. Method used in this research was the analysis of water quality test, protein content,

fat content, carbohydrate content, calorie content, organoleptic test and TPC test. The study concluded that the addition of chitosan could improve quality of anchovy, which could be seen in the test values. (Achmad, M. J., et al.,2021) .

Anchovies are among the largest fish catch worldwide. The anchovy fillet industry generates a huge amount of biowaste (e.g., fish heads, bones, tails) that can be used for the extraction of several potentially valuable bioproducts including omega-3 lipids. study demonstrate that anchovy leftovers after the fish oil extraction process can be efficiently used as a starting co-substrate for the production of biogas in a modern biorefinery. Finally, due to the huge amount of biowaste generated every year from the landing of small pelagics in the EU, a new “blue-biorefinery” scenario can be imagined at a large- scale in the next years for Mediterranean nations. (Paone,E.,et al,. 2021).

Review highlights both conventional and innovative anchovy-based food items. Anchovies powdered and cubes were available in the markets and became very popular as flavouring or seasoning ingredient in cooking. Anchovy-based products have breakthrough potential in food industries due to their high nutritional value, which gives added value to the products and offers a distinctive taste of anchovies. (Kari, N. M,et al., 2022).

This study aimed to produce anchovy protein isolate (API) and evaluate its physical, chemical, and sensory properties. The API was prepared from defatted anchovy flour. Isolation of anchovy protein was carried out using a pH-shifting method. The API was then analyzed for its physicochemical (bulk density, color, proximate) and sensory properties. the smell and taste values of fish liver oil, dried fish, and TMA of API were higher than those of SPI. Overall, API could be used as an excellent source of protein and can be applied in the formulation of foodstuffs. (Canti, M.,et al., 2022).

Scaffaro, R.,et al., (2022).conducted work wherein 10% and 20% of anchovy fishbone powder (EE), obtained by market waste, were microbiological and mechanical tested and subsequently added to polylactic acid (PLA) and to a commercial blend of biodegradable co-polyesters. In this work, innovative and green composites filaments were produced by adding 10 or 20% of anchovy fishbone waste to two different biopolymeric matrices (PLA and MB). For both matrices, formulation with 10% of filler turned out to be easy printable for FDM. (Scaffaro, R.,et al., 2022).

The research aims to determine the effect of adding anchovies fish meal in improving the quality of noodles made from sago. Sago noodle quality was evaluated through nutritional composition analysis and sensory properties. Protein content (1.31-4.06%) of anchovies fish meal-added noodle samples was very high, so that it had a significantly different effect than the control ($p<0.05$). Ash and calcium content showed the highest value in the 7% anchovies fish meal noodle which is 3.58% and 670.39 mg, respectively. The sensory properties quality of aroma noodles was 4.50, and taste 4.30. (Litaay, 2022).

THE CHOICE OF ANCHOVIES FOR THIS RESEARCH

Fish and seafood are foods of high nutritional value, rich in essential amino acids, high-quality proteins, many vitamins (A, B, and D) and minerals (iron, calcium, zinc, selenium), and especially omega-3 polyunsaturated fatty acids (Cardoso et al., 2013; Nesheim et al., 2015).

Strong scientific evidence is confirming the beneficial effects of fish consumption on human health, including cognitive development, mental health, immune system, prevention of anemia, cardiovascular disease, and dementia (Béné et al., 2015; Golden et al., 2016).

The European Food and Nutrition Action Plan 2015–2020 encourages Member States to promote local affordable and healthy dietary initiatives to support a sustainable food system, particularly in schools and public institutions where advertising on eating behaviour and food preferences is needed. The present findings highlight the high nutritional value and healthiness of serving locally caught fish in school meals, which plays a strong role in teaching good dietary habits for a lifetime. Further initiatives are needed to encourage responsible fish consumption during early life to promote a sustainable food system. (Bonanomi, 2019).

Eating fish and seafood is very important, not only for its proven health benefits but also for its positive impact on the environment. (Sandra Marinac Pupavac et al.,2022)

As one of food sources, fish provides sufficient nutrition to human. Diverse nutrients in fish make fish an important nutrient source available easily across the

globe. Fish is proven to possess several health benefits, such as anti-oxidation, anti-inflammation, wound healing, neuroprotection, cardioprotection, and hepatoprotection properties. Fish proteins, such as immunoglobins, act as defense agents against viral and bacterial infections and prevent protein-calorie malnutrition (Chen et al., 2022)

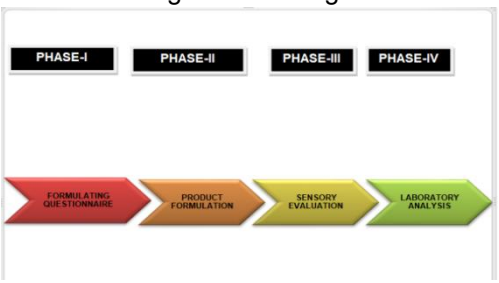
Every day large amounts of fish waste are produced and grossly discarded in markets around the world causing environmental and hygiene issue. The use of these scraps for the production of materials with higher added value can definitely contribute to solve this problem. (Scaffaro, R.,et al., 2022).

METHODOLOGY

Diagram I

PHASE-I E-SURVEY

To find out the preference of consumers about their likings on non-vegetarian flavour



enhancement in Ready to eat Powders.

Questionnaire was prepared and administered through Google forms.

Surveys are a commonly used strategy for gaining insights. They are often seen as cost effective in terms of time and resources required, but the challenges involved in conducting and processing paper-based surveys can be considerable. Online surveys offer an alternative, particularly now that people have better access to computers and the Internet, and also since the available software has recently become more user-friendly and in some cases, free to the user (Harlow, A. 2010).

Figure 3 QUESTIONS B

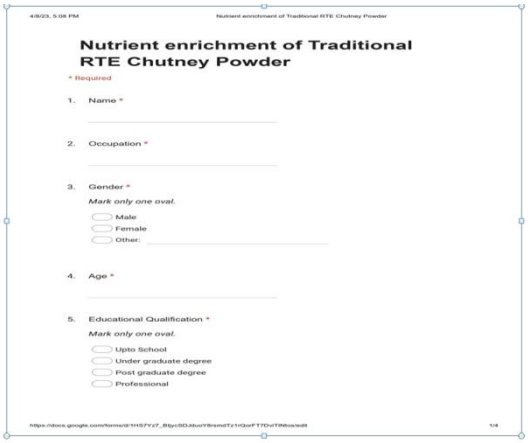


Figure 2 QUESTIONS A

Figure 2 QUESTIONS A

Figure 3 QUESTIONS B

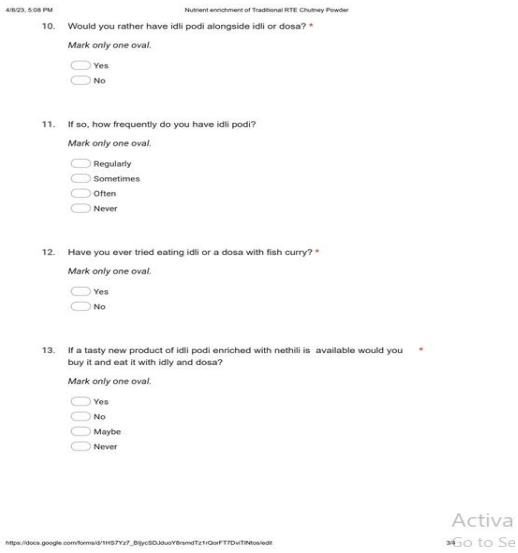


Figure 4 QUESTIONS C

Figure 5 QUESTIONS D

Phase-II

FORMULATION OF THE PRODUCT

The anchovy (*Engraulis encrasicolus*) fish samples were obtained from KASIMEDU FISH LANDING CENTER, near Chennai harbour Undamaged good quality selected fishes of same length and diameter were

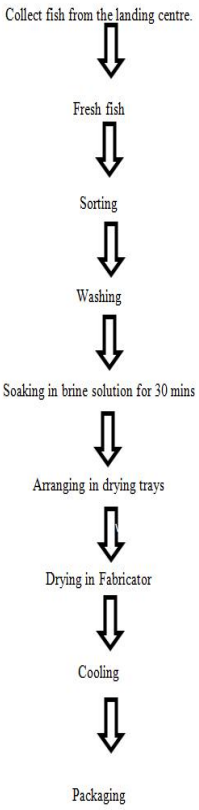
immediately iced and transported using an ice box within 2 hours to the area for drying.
Raw anchovy samples were cleaned, carefully washed with potable water and drained. Fish samples were mixed thoroughly with dry salt (20% w/w) and subjected to drying

SOLAR DRYING PROCESS OF ANCHOVY IN THE FABRICATOR

Limitations of sun drying can be improved by raising the drying fish rack off the ground on wooden frames which allows air to circulate in all the directions, that facilitates water evaporation from both sides (Sankat and Mujiaffar, 2004).
Solar drying is an improved method ofsun drying. It minimizes or stops some of the limitations of open sun drying (FAO, 1981; Relekar et al., 2014). Solar drying differs from open sun drying in a structure, often very simple in construction, which is used to enhance effect of the insulation (Yu, Siaw, and Idrus, 1982).
Bereket Abraha et al., (2017) have researched and reported the quality of the fish products dried in the solar tent drier was superior compared to that of open sun rack-dried products. Based on this a drier was fabricated for the drying process of anchovies as shown in Fig.…

Figure 6 SOLAR DRYER

DEHYDRATION METHODOLOGY



The drying process was done for 10 days to obtaining the fine dried fish)

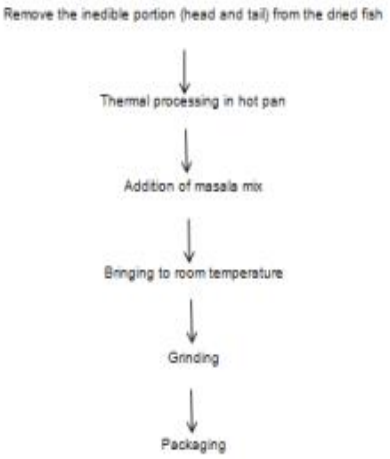
Figure 7 DRIED ANCHOVY

Figure 8 PREPERATION OF ANCHOVY POWDER

PREPARATION OF PRODUCT MIX

1. **Preparaion of Anchovy Powder**
2. **Preparation of control chutney Powder**

PREPERATION OF THE ANCHOVY POWDER



PREPERATION OF IDLY CHUTNEY POWDER

Ingredients:

- Urad dhal
- Toor dhal
- Red chilly
- Curry leaves
- Sesame seeds
- Garlic
- Salt
- Dried anchovy

After numerous improvisations from the above ingredients, the chutney powder was made for 100gm.

The product mix was prepared with **one control** and **Three Test samples** in Different Concentrations

RTE CURRY POWDER

Ingredient	Control	Trial 1	Trial 2	Trial 3
Urad Dhal (g)	65.0	62.5	60.5	60.5
Thoor Dhal (g)	23.5	20.5	20.0	17.5
Salt (g)	1.0	0.50	0.50	0.50
Spice powder mix (g)	11.5	11.5	11.5	11.5
Anchovy powder (g)	-	5.0	7.5	10
Total (g)	100	100	100	100

PRODUCT MIX FORMULATION

TABLE 2- FORMULATION OF PRODUCT MIXES

Figure 9 FORMULATED PRODUCT

The prepared product was packed in a sterile glass container and stored at room temperature, in a dark place away from the sun light.

PHASE - III

SENSORY EVALUATION OF THE PRODUCT FOR ITS APPECTANCE

Food sensory testing involves the use of the human senses in the objective evaluation of food products. Characteristics such as appearance, texture, odour and taste are analysed by trained testers to assess product quality or derive opportunities for improvement.

The sensory evaluation of Nutrient Enrichment of RTE Chutney Powder was done on 07.01.2023 with a five point Hedonic scale to test the various parameters such as taste, texture, aroma, appearance and overall acceptability.

The sensory evaluation of this product was carried out by 30 semi-trained panellists comprising of students who have previous experience in sensory evaluation of food products.

The order in which participants tasted the samples was not controlled.

SENSORY EVALUATION

Figure 10 SENSORY EVALUATION

SENSORY CARD:

Date:

Name:

Hi, I am Jeremiah Pandian J.S, senior year student pursuing MSc. Food Chemistry and Food Processing, from Loyola College. This survey is for the sensory evaluation of "Nutrient Enrichment of traditional RTE Chutney Powder using Anchovy." incorporated with different concentrations of Anchovies, as a part of my research project.

Please evaluate the coded samples for each sensorial parameter including color, aroma, texture, flavor, and overall acceptance based on your degree of liking.

(1 = dislike very much; 2= dislike slightly; 3 = neither like nor dislike; 4 = like slightly; 5 = like very much).

Note**

** **SEAFOOD ALLERGEN WARNING This is a non-vegetarian food product and people who are sensitive to Fish and fish food products are kindly requested to refrain from tasting the samples.**

SAMPLE	TASTE	TEXTURE	AROMA	APPEARANCE	OVERALL ACCEPTABILITY
A					
B					
C					
D					

Thank you for your feedback.

S.no	Parameters	Test method
1	Moisture content	IS 11536 (2007)
2	Fat content	IS 1153:1992, IS 12711
3	Protein	ts 6287
4	Total Ash	IS 1797:1985
5	Omega 3 fatty acid	RVNL/SOP/073

PHASE IV – ANALYSIS FOR PROXIMATE COMPOSITION OF THE MIX AND ITS OMEGA FATTY ACID CONTENT

LABORATORY TESTING

PROXIMATE ANALYSIS: The value incorporated RTE Powder was subjected to proximate analysis to determine its nutrient composition, namely moisture, fat, protein and ash using approved method as mentioned below:

TABLE-3 LABORATORY TEST AND METHODS

MOISTURE CONTENT

IS 11536 (2007): Processed - Cereal based complementary foods - Specification (Second Revision)

The method is based on removing soil moisture by oven-drying a soil sample until the weight remains constant. The moisture content (%) is calculated from the sample weight before and after drying.

FAT CONTENT TEST

Simple extraction method

Dissolve 10 g sample in 10 mJ of warm water and introduce Into Moj »nnier fat extraction tube or similar apparatus. Add 25 ml peroxide free diethyl ether. Cork the tube and shake vigorously for I minute. Add 25 ml of petroleum ether and shake vigorously for 30 seconds. Let it stand for 30 minutes or until separation is complete. Draw off the fat solution into a suitable flask (previously dried at 100DC, cooled and weighed). Repeat the extraction and subsequent operations twice more. Evaporate the ether and dry the fats for I hour at IOODC. Cool and weigh.

Calculation:

Fat percent by mass (dry basis) = $\frac{M1}{M2\times(100-M)}$

M 1 - mass in g of extracted fat

M 2 mass in g of the prepared sample taken,

M = percentage of moisture in the material

TEST FOR PROTEIN

The assembly consists of a round bottom flask A of I 000 ml capacity fitted with a rubber stopper through which passes one end of the connecting bulb tube B. The other end of the bulb B is connected to the condenser C which is attached, by means of a rubber tube, to a dip tube D which dips into a known quantity of standard sulphuric acid contained in a beaker E of 250 ml capacity.

Figure 11 PANELISTS PERFORMING SENSORY EVALUATION

Figure 12 APPARATUS FOR PROTEIN TEST

TOTAL ASH

Principle involved is that when a known weight of feed is ignited to ash, the weight of ash thus obtained is expressed in terms of percentage.

Procedure

Find out the weight of a clean dry crucible. Place about 2 g of sample and weigh this to find out accurate weight of the sample taken. . Carefully place the weighed crucible over electric burner. The crucible should be partially opened. . The sample will get charred with initial expulsion of smoke. Place the crucible in a muffle furnace and heat to 600ºC. Keep it for 2 hours. At this temperature all organic matter will be burnt leaving behind minerals. Remove the crucible from the furnace carefully and cool it in a desiccator to room temperature and weight again.

TOOLS USED FOR STATISTICAL ANALYSIS

- For determining the significant difference between the groups of samples one way Anova, SPSS Software was used by the Researcher.
- For doing the comparison studies t-Test; two samples assuming equal variables, Microsoft Excel.v2010 software was used by the Researcher.

CHAPTER – V

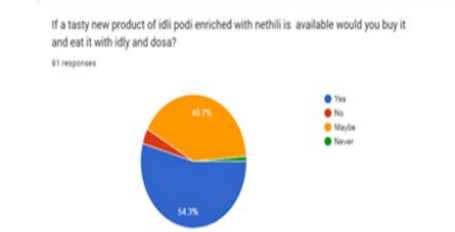


Figure 16 Q – RESULT D

RESULTS AND DISCUSSION:

The study on **Enrichment of Traditional Chutney Powder Using Anchovies** was carried out in a well-designed manner to meet the objective. The ready to eat chutney powders were prepared and evaluated, and the results are presented and discussed in this section

PHASE-1

The response to the E survey are summarised and recorded below:

The consumer's likings on seafood incorporated chutney powders was obtained from 100 respondents.

DEMOGRAPHIC DETAILS:

A total of 100 responds was collected,
51- Females and 49-males,
Age category: 18-23 yrs.

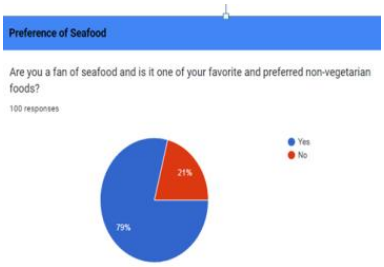


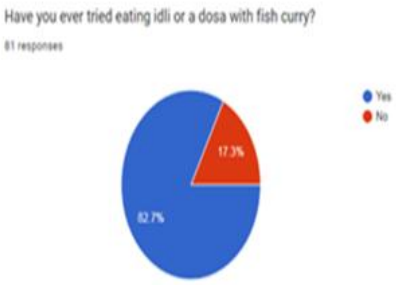
Figure 13 Q – RESULT A

79% of respondents responded 'yes' for seafood being their non vegetarian food preference and 21% respondents responded 'No' for the question.

Figure 14 Q – RESULT B

56% of respondents relish Nethili fish and 25% were not sure and only 19% do not like the fish.

Figure 15 Q – RESULT C

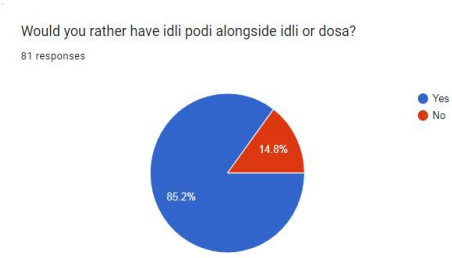


82.7% respondents has tried eating idlis with fish curry and 17.7% has not tried.

Figure 16 Q – RESULT D

54.3 % responded yes they will buy a new product that is enriched with anchovies and 45.7 said maybe. This reveals there is a high preference for consumers liking if this formulated product with anchovies is made available in the market.

Figure 17 Q - RESULT E



A Yes or No question was asked to the respondents whether they would have idli podi alongside with idli or dosa, 85.2% said yes and 14.8% said no for the question.

Figure 18 Q- RESULT F

Regarding the frequency of consuming chutney powder, 65.4% responded sometimes, 17.3% responded often, 7.4% responded regularly and 9.9% responded never.

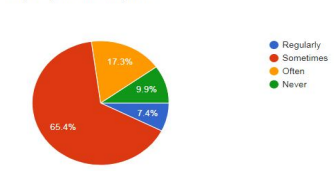
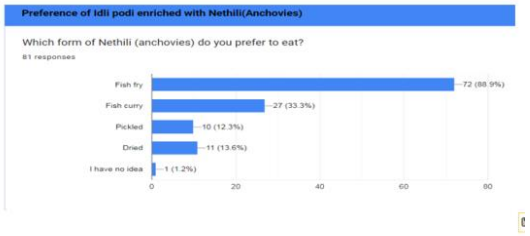


Figure 19 Q- RESULT G

From the following question 'which form of



Nethli (anchovies) do you prefer to eat'? Most of respondents preferred it in the fried form. Since the question was an open ended question the respondents were allowed to select more than one option among that they preferred Fish fry the most followed by Fish curry, Pickled and Dried.

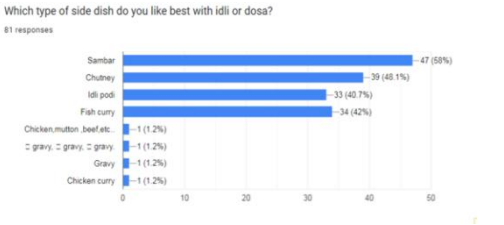


Figure 20 Q – RESULT H

Multiple preferences and choices were given to respondents and it resulted in the following observation.58% preferred sambar, 48% chutney, 40.7% preferred idli podi, 34% fish curry, 1.2% chicken, mutton, beef, ect. Gravy - 1.2%, Chicken curry - 1.2%.

Figure 21 Q- RESULT I

For the question 'would you buy the product even if it is slightly costly'

56% respondents responded 'yes' they will buy the product even if it is costly. 33% responded 'maybe' they will buy or not buy the product and 9.9% responded 'No'.

CONCLUSION OF E-SURVEY

According to the data collected from the E Survey, 95% of people are willing to buy the new product formulated with anchovies, and 90.01% are willing to buy the product even if it is slightly more expensive, the survey also shows the influence of non-vegetarian foods predominantly liked by many ono vegetarian consumers compared to vegetarian foods. For most the consumers, purchase of non-vegetarian products were on a weekly basis. Kumar, N., and Kapoor, S. (2014).

85.2% of the respondent responded that they consume chutney powder with the traditional breakfast.This E survey gives us an overall positive picture with regard to utilising the idli podi and proceeding to **Enrich the Traditional Chutney Powder Using Anchovies.**

RESULT OF PHASE II – PRODUCT MIX

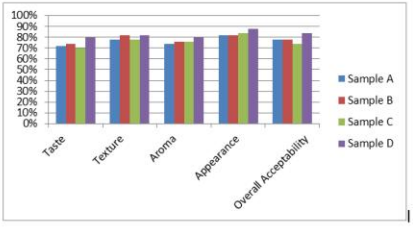
Figure 22 FORMULATED PRODUCT IN A GLASS CONTAINER

PRODUCT MIX FORMULATION

One control and three test samples with different proportions of anchovy powder (5%, 7.5% and 10 %) was formulated and prepared.

RESULT OF PHASE III – SENSORY EVALUATION

Sensory evaluation plays a vital role in the assessment of acceptance of novel food products and preferences for different cuisines. This process provides significant and valuable information to the food-processing industries and food scientists regarding the sensory quality of food products. Sensory evaluation is a critical component to that process. Historically, sensory evaluation has often been associated with product experts, and later as a more passive member of the product development team. Currently, the new challenges facing the food industry are



progressively transforming sensory to a

more proactive role, responsible for generating new product ideas based on unique sensory properties or unique consumer segments identified only through sensory behaviour. Sidel, J. L., and Stone, H. (1993).

According to the data collected from the Sensory evaluation done by 30 sensory panelists, the Test-3 sample has secured an average of 82.8%, with an overall acceptability score of 84% and liked the most by the sensory panelist.

Figure 23 SENSORY EVALUATION GRAPH

Sample A-Control, Sample B- T1, Sample C-T3, Sample D-T3

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Taste	Between Groups	5.492	3	1.831	2.056	0.110
	Within Groups	103.300	116	.891		
	Total	108.792	119			
Texture	Between Groups	.692	3	.231	.375	0.771
	Within Groups	71.233	116	.614		
	Total	71.925	119			
Aroma	Between Groups	1.758	3	.586	.650	0.584
	Within Groups	104.567	116	.901		
	Total	106.325	119			
Appearance	Between Groups	1.292	3	.431	.749	0.525
	Within Groups	66.700	116	.575		
	Total	67.992	119			
Overall Acceptability	Between Groups	3.440	3	1.147	2.175	0.095
	Within Groups	61.142	116	.527		
	Total	64.581	119			

The overall acceptability score of Control was 4.1, Trial 1 was 4.1, T2 was 4.0, and T3 was 4.4.

TABLE – 4 RESULTS OF ONE WAY ANOVA FOR SENSORY EVALUATION

There is no significance variation in the sensory evaluation of RTE Curry powder between the samples. Since no statistical significance was observed among trial samples and all three are acceptable, Trial 3 with highest proportion of anchovy powder (10%) with an overall acceptability score of 4.4 was chosen for further analysis.

TABLE – 5 RESULTS OF LABORATORY ANALYSIS

S.no	Parameters	Units	Results Test samples/T3
1	Moisture	g/100g	5.60
2	Fat Content	g/100g	4.90
3	Protein	g/100g	20.90
4	Total Ash	%/100g	5.10
2	Omega 3 fatty acid	g/100g	1.1

The following are the results obtained from proximate analysis of the given ready to eat idly chutney powder.

The moisture content was **5.60 g/100g**. Low moisture content is desirable as its related to low water activity of powder, which is important for powder stability during storage. (Abdullah, Z., 2020). Moisture, per cent by weight (not more than) 10.0 according FSSAI standards for powdered foods, thus the product is within the safety standards of FSSAI.

From the results obtained from the laboratory the fat content in the product was said to be **4.9g/100g**. The fat content in product is more or less the same in other Idli chutney powders which ranges from 4% - 12%. The fat content in the idly chutney powder basically due to lentils, chilly and anchovies added to it.

From the results obtained from the laboratory the protein content in the product was said to be 20.90 g/100g in the test sample. The protein content in the idli chutney powder was due to the protein available in pulses, chillies and curry , and anchovies. The protein content of anchovy ranged from 17.24 to 16.94%. Kaya, Y., and Turan, H. (2010).

From the results obtained from the laboratory the total ash content in the product was said to be **5.10 g/100g** in the test sample.

On laboratory analysis the Omega 3 fatty acid content of chutney powder with 10% anchovies powder (T3) was found to be **1.1g/100g**. Fish is healthy part of the human diet due to the high content of long chain n-3 polyunsaturated fatty acids (n-3 PUFA) as eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3). Di Bella, (2022). EPA and DHA are forming compounds of Omega 3 anchovy (*Stolephorus Sp.*) oil concentrate. Content analysis results, anchovy fatty acid 1% using spectrophotometer GC-MS. Previous research also states that the anchovy *(Stolephorus Sp.*) is a cheap local fishery products and very easy to find. Anchovy classified as oily fish contains high category of omega-3 fatty acids. (Mattimu, 2016).

SHELF LIFE STUDY AFTER 60 DAYS

TABLE - 6

RESULTS OF t-Test TWO SAMPLES ASSUMING EQUAL VARIANCE

t-Test: Two-sample Assuming Equal Variances

Sensory Attributes		Min score	Max score	Mean	SD	T-value	P Value
Taste	A	1	5	3.786	0.686	8.231	0.000
	B	1	5	4.929	0.262	8.231	0.000
Texture	A	1	5	3.821	0.669	6.128	0.000
	B	1	5	4.75	0.44	6.128	0.000
Aroma	A	1	5	3.571	0.634	8.884	0.000
	B	1	5	4.821	0.39	8.884	0.000
Appearance	A	1	5	3.892	0.566	8.158	0.000
	B	1	5	4.892	0.314	8.158	0.000
Overall acceptability	A	1	5	3.75	0.518	9.972	0.000
	B	1	5	4.892	0.314	9.972	0.000

Shelf-life of food products can be regarded as the period of time during which a product could be stored until it becomes unacceptable from safety, nutritional, or sensory perspectives. Shelf-life estimation of food products and beverages has become increasingly important in recent years due to technological developments and the increase in consumer interest in eating fresh, safe and high quality products. The shelf-life of the majority of food products is determined by changes in their sensory characteristics. Giménez, A., Ares, F., and Ares, G. (2012).

Test of significance revealed that there is a significant difference in the mean Taste, Texture, Aroma, Appearance and Overall acceptability between the control and experimental samples. It is Evident the experiment sample had a higher mean compared to that of the control sample.

It was observed through this study that the formulated chutney powder with 10 % anchovies was acceptable on sensory evaluation. Overall, the proximate analysis of the formulated powder is well balanced with all essential nutrients. Further the presence of anchovies add value to this product as they are nutrient rich fishes. Stored in glass containers the powder was shelf stable for 60 days.

SUMMARY

- It is concluded that consuming traditional RTE Chutney Powder using Anchovy will satisfy the Needs of fish lovers and will add variety and value to the existing RTE chutney powder on the market shelf.
- The E-survey conducted show the high preference and consumer liking for this formulated product if made available.
- The sensory acceptance of chutney powder with 10 % anchovies also scored well among the sensory panelists.
- The nutritional composition of RTE Chutney powder meets the FSSAI specification for moisture requirement for powdered food products.
- The presence of omega 3 fatty acids in this product plays as an essential component to tackle health hazards.
- The shelf life study proves that the product is stable and tasty even after 60 days in the shelf.

It was observed through this study that the formulated chutney powder with 10 % anchovies was acceptable on sensory evaluation. Overall, the proximate analysis of the formulated powder is well balanced with all essential nutrients. Further the presence of anchovies adds value to this product as they are nutrient rich fishes. Hence the product is safe for human consumption and has a good taste.

CHAPTER – VI

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Harnessing Artificial Intelligence to Detect, Protect, and Conserve Endangered Marine Flora and Fauna: A Review of Technological Applications and Case Studies

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Abstract

Endangered marine flora and fauna face threats from over exploitation, habitat destruction, climate change, and illegal trafficking. The adoption of Artificial Intelligence (AI) in conservation offers innovative solutions for both detection and protection. This article explores AI applications in image recognition, predictive analytics, IoT integration, and drone surveillance for marine biodiversity conservation. It delves into detailed case studies, including CoralNet's reef monitoring, Global Fishing Watch's illegal fishing detection, and AI-based anti-poaching systems. By analyzing existing technologies and their impact, the study highlights future directions to enhance conservation efforts globally.

Introduction

Marine ecosystems are crucial for sustaining biodiversity, regulating global climate, and providing livelihoods. However, these ecosystems are under severe threat due to illegal poaching, unsustainable practices, and environmental degradation. Recognizing the urgency of protecting endangered marine species and habitats, researchers are increasingly turning to AI technologies. AI provides powerful tools for detecting trafficking, identifying species, and predicting hotspots of illegal activity. This article aims to review AI applications in marine conservation, with a focus on endangered flora and fauna, and showcase the transformative potential of technology in mitigating human-induced threats.

A comprehensive exploration of endangered flora and fauna trafficking, how AI technologies could address these issues, and an elaborated list of endangered species from India and globally.

Endangered Flora and Fauna: India and Global

India

Flora:

Here's a comprehensive exploration of endangered flora and fauna trafficking, how AI technologies could address these issues, and an elaborated list of endangered species from India and globally:

Trafficking of Endangered Flora and Fauna

Trafficking of endangered marine flora and fauna is a significant threat to global biodiversity. It involves the illegal trade, overharvesting, and smuggling of species for various purposes:

Fauna: Marine animals like sharks, rays, turtles, and dolphins are trafficked for their meat, shells, fins, oils, and other products.

Flora: Mangroves, seagrasses, corals, and seaweeds are extracted for medicinal uses, decorative purposes, or as raw materials for industries.

Drivers of Trafficking

High demand for exotic marine species in international markets.

Limited enforcement of regulations in coastal and maritime zones.

Lack of awareness among local populations regarding the ecological importance of these species.

Weak supply chain tracking capabilities.

Role of AI in Detecting and Protecting Endangered Species

Artificial Intelligence provides transformative capabilities to combat the trafficking of marine species and flora:

Detection Using AI

Image Recognition:

AI-based tools like **Finfinder** can identify trafficked shark and ray species, even in mixed cargo.

AI-enhanced customs scanners can flag illegal items at borders and ports.

Behavioral Pattern Analysis:

AI systems analyze shipping data, tracking anomalies indicative of smuggling operations.

Natural Language Processing (NLP) tools monitor social media and online platforms for hidden listings or coded languages related to wildlife trade.

Protection Using AI

Monitoring Marine Habitats:

AI-powered drones and underwater cameras help track endangered species in real-time.

Acoustic AI sensors detect sounds of whales, dolphins, or other marine mammals, alerting conservationists to potential risks.

Predictive Analytics:

AI models predict trafficking hotspots based on historical data, weather patterns, and socio-economic factors.

Machine learning algorithms forecast the decline of vulnerable species.

Real-Time Ecosystem Monitoring:

IoT-enabled devices monitor mangroves, coral reefs, and seagrasses to detect and prevent habitat destruction.

Community Engagement Tools:

AI-powered apps educate local communities about trafficking risks and allow them to report suspicious activities.

Endangered Flora and Fauna: India and Global

India

Flora:

Avicennia marina (Grey Mangrove): Vital for stabilizing coastlines, but threatened by deforestation.

Rhizophora mucronata (Red Mangrove): Facing habitat loss.

Cymodocea serrulata (Seagrass): Critical for marine biodiversity but vulnerable to coastal pollution.

Sargassum spp. (Seaweed): Overharvesting impacts its populations.

Fauna:

Dugong (*Dugong dugon*): Threatened by fishing activities and habitat loss.

Knifetooth Sawfish (*Anoxypristis cuspidata*): Critically endangered due to overfishing.

Indian Ocean Humpback Dolphin (*Sousa plumbea*): Threatened by bycatch and habitat degradation.

Ganges Shark (*Glyphis gangeticus*): Rare species impacted by water pollution.

Global

Flora:

Posidonia oceanica (Seagrass): Essential for carbon sequestration but vulnerable to human activities.

Macrocystis pyrifera (Giant Kelp): Forms underwater forests but faces threats from warming oceans.

Coralline Algae: At risk due to ocean acidification.

Fauna:

Vaquita (*Phocoena sinus*): The world's rarest marine mammal, threatened by gillnets.

Humphead Wrasse (*Cheilinus undulatus*): Overfished for food and the aquarium trade.

Leatherback Turtle (*Dermochelys coriacea*): Threatened by plastic pollution and habitat destruction.

Green Turtle (*Chelonia mydas*): Facing threats from fishing gear and loss of nesting sites.

The trafficking of endangered marine flora and fauna demands urgent action through technology and conservation initiatives. AI technologies—when integrated with traditional conservation methods—offer unprecedented opportunities for detection, protection, and long-term sustainability. By identifying trafficking hotspots, monitoring habitats, and engaging communities, AI can catalyze global efforts to preserve marine biodiversity.

Case studies and step-by-step technical explanations of how AI can be leveraged to detect and protect endangered flora and fauna:

1. AI for Image Recognition in Wildlife Trafficking

Case Study: Fin Finder Tool for Shark Fin Identification

Overview: This AI tool assists customs officials in identifying shark and ray species using confiscated fins. By analyzing the fin's texture, shape, and color, AI models can accurately identify the species, including endangered ones protected under CITES (Convention on International Trade in Endangered Species).

Step-by-Step Technical Details

Dataset Creation:

Collect a labeled dataset of shark fin images for training.

Classify images by species (e.g., Great Hammerhead, Whale Shark).

Preprocessing:

Resize images to a standard resolution (e.g., 256x256 pixels).

Normalize pixel values to improve computational efficiency.

Use augmentation techniques like rotation and scaling for variability.

Model Training:

Use a CNN-based architecture (e.g., ResNet50 or EfficientNet).

Train the model with cross-entropy loss to handle multiclass classification.

Deployment:

Integrate the trained model into a mobile or web application.

Customs officers can upload images, and AI predicts the species in real-time.

Enhancements:Continuously improve the model by incorporating new data from field deployments.

Impact: This system helps law enforcement quickly detect illegal shark fin trafficking, reducing harm to endangered species.

2. AI in Predictive Analytics for Conservation

Case Study: Wildlife Crime Prediction by TRAFFIC and WWF

Overview: Predictive analytics tools are being used to identify potential wildlife trafficking hotspots. AI analyzes data such as historical poaching incidents, geographic trends, and socio-economic factors.

Step-by-Step Technical Details

Data Collection:

Compile datasets of wildlife trafficking incidents, transportation routes, and known smuggling methods.

Feature Engineering:

Extract key features such as geographic coordinates, time of year, and species involved.

Use tools like Python's Pandas or NumPy to process and organize data.

Model Selection:

Train machine learning models like Random Forest or Gradient Boosting to predict trafficking patterns.

Use classification techniques to categorize regions as high, medium, or low risk.

Implementation:

Combine AI outputs with GIS mapping tools (e.g., ArcGIS) to visualize hotspots.

Law enforcement agencies can focus surveillance on high-risk areas.

Monitoring:

Continually update the model with real-time incident reports to improve accuracy.

Impact: Proactive monitoring enables conservation teams to intervene before poaching or trafficking occurs.

3. AI in IoT-Integrated Marine Monitoring

Case Study: Global Ocean Observation Using Smart Sensors

Overview: IoT-enabled devices equipped with AI monitor critical habitats like mangroves and seagrasses to detect illegal logging and habitat destruction.

Step-by-Step Technical Details

IoT Device Setup:

Deploy IoT sensors (e.g., temperature, salinity, acoustic) in key ecosystems.

Connect sensors to cloud platforms for centralized data storage.

Data Processing:

Use AI models to analyze sensor data in real-time.

For example, acoustic data from underwater sensors can detect illegal trawling or marine mammal movements.

Visualization:

Develop dashboards using platforms like Tableau to visualize ecosystem health.

Alert System:

Implement automated alert notifications for anomalies.

For example, sudden changes in water temperature may indicate habitat disturbances.

Collaboration:

Share data with stakeholders, including conservation agencies and local authorities.

Impact: Real-time monitoring ensures faster response to threats and prevents long-term damage to habitats.

4. AI for Coral Reef Health Monitoring

Case Study: CoralNet and Reef Restoration Projects

Overview: CoralNet uses AI to analyze underwater reef images, identifying coral species and assessing damage caused by climate change and human activity.

Step-by-Step Technical Details

Dataset Labeling:

Create a labeled dataset of coral images, tagging types (e.g., Staghorn Coral, Brain Coral) and health status (healthy, bleached, or dead).

Model Architecture:

Use image segmentation models like U-Net to classify pixels corresponding to specific coral types.

Cloud Integration:

Upload processed data to a cloud platform for large-scale analysis.

Visualization:

Generate maps of coral reefs, highlighting healthy and bleached areas.

Intervention:

Conservationists can use the AI-generated data to prioritize reef restoration efforts.

Impact: Detailed insights into reef health enable targeted conservation and long-term planning.

Comprehensive List of Endangered Flora and Fauna for Focus.

Endangered Flora

India:

Avicennia marina (Grey Mangrove): Critical for coastal stability.

Cymodocea serrulata (Seagrass): Vital for dugong habitats.

Rhizophora mucronata (Red Mangrove): Facing habitat loss.

Global:

Posidonia oceanica: The "lungs of the Mediterranean."

Macrocystis pyrifera (Giant Kelp): Key in kelp forest ecosystems.

Coral-associated Halimeda spp.: Essential for reef-building.

Endangered Fauna

India:

Dugong (Dugong dugon): Threatened by fishing nets and habitat loss.

Ganges Shark (Glyphis gangeticus): Critically endangered in rivers and estuaries.

Global:

Vaquita (Phocoena sinus): The world's rarest marine mammal.

Leatherback Turtle (Dermochelys coriacea): Threatened by plastic pollution.

Artificial Intelligence has the potential to transform conservation efforts for endangered marine flora and fauna. By combining detection methods (image recognition, predictive analytics) with protection strategies (IoT monitoring, automated alerts), AI provides a robust framework to address trafficking and

habitat loss. Future research and collaboration between technologists and conservationists can further refine these tools for global impact.

Humphead Wrasse (*Cheilinus undulatus*): Overfished for food and the aquarium trade.

Detailed Case Studies

Case Study 1: AI-Powered Image Recognition

AI-based image recognition models, powered by Convolutional Neural Networks (CNNs), are revolutionizing species identification. Tools like CoralNet analyze underwater images to detect coral bleaching and identify coral species. Fin Finder assists customs officials in identifying trafficked shark and ray species. These technologies enhance the ability of conservationists and authorities to combat illegal wildlife trade effectively.

Case Study 2: IoT Integration for Real-Time Monitoring

The integration of IoT devices with AI enables real-time monitoring of marine ecosystems. Underwater drones equipped with smart cameras analyze live feeds to identify species like turtles, corals, and sharks. Acoustic sensors powered by AI detect sounds of marine mammals, aiding conservation efforts. IoT buoys equipped with AI tools monitor pollution levels and send alerts to stakeholders about environmental changes threatening marine habitats.

Case Study 3: AI for Anti-Poaching Surveillance

Organizations like WWF utilize AI-enhanced drones and thermal imaging cameras to detect illegal activities in marine protected areas. Predictive analytics identifies poaching hotspots by analyzing environmental and historical data. AI-powered alerts enable swift intervention, preventing harm to endangered species.

Case Study 4: AI in Illegal Marine Trade Monitoring

AI systems, such as TRAFFIC's Wildlife Trade Monitoring System, scan e-commerce platforms, social media, and marketplaces for suspicious listings of endangered species. NLP-based tools decode hidden terms and flag illegal activities, providing critical data to law enforcement agencies.

Conclusion

The application of Artificial Intelligence in marine conservation offers unparalleled opportunities to detect, protect, and preserve endangered species and habitats. From image recognition to IoT integration, AI has the potential to address complex challenges in monitoring and combating threats to marine biodiversity. As AI technologies continue to evolve, their role in conservation will become increasingly vital. Future efforts must focus on expanding datasets, enhancing community engagement, and integrating AI with global policy

frameworks to ensure sustainable protection of marine ecosystems.

Artificial Intelligence (AI) can play a transformative role in combating the trafficking of endangered marine flora and fauna. Here's how it can be utilized for both detection and protection:

Detection

Image Recognition:

AI-powered image recognition tools can analyze photos and videos to identify trafficked species, even when they are disguised or partially hidden. For example, tools like Fin Finder help customs officials identify shark and ray species in real-time.

Natural Language Processing (NLP):

AI can scan online marketplaces, social media, and e-commerce platforms to detect coded language or suspicious listings related to wildlife trafficking. Systems like WWF's cyber-surveillance platform use NLP to decode hidden terms and flag illegal activities.

Behavioral Pattern Analysis:

AI can analyze patterns in shipping data, user behavior on online platforms, and transaction histories to identify potential trafficking networks. This helps law enforcement focus on high-risk areas.

Automated Scanning at Ports:

AI-driven systems can enhance X-ray and scanning technologies at ports to automatically detect illegal wildlife products hidden in cargo or luggage.

Protection

Monitoring Ecosystems:

AI-powered drones and satellite imagery can monitor habitats like mangroves, coral reefs, and seagrass meadows to detect illegal activities such as logging, fishing, or habitat destruction.

Predictive Analytics:

AI can predict trafficking hotspots and vulnerable species by analyzing historical data, environmental changes, and socio-economic factors. This allows for proactive conservation measures.

Real-Time Alerts:

AI systems can send real-time alerts to authorities when suspicious activities are detected, enabling swift action to prevent trafficking.

Community Engagement:

AI chatbots and apps can educate local communities about the importance of protecting endangered species and provide them with tools to report illegal activities.

By integrating AI with traditional conservation efforts, we can create a robust system to detect, deter, and protect endangered marine flora and fauna.

A detailed breakdown of how Artificial Intelligence (AI) can be used to detect and protect endangered

marine flora and fauna, along with specific tools and techniques:

Detection

Image Recognition:

How it works: AI-powered image recognition systems analyze photos and videos to identify species, even when disguised or partially hidden. These systems use deep learning algorithms trained on large datasets of images.

Tools:

Fin Finder: Helps customs officials identify shark and ray species in real-time.

Wildbook: Uses computer vision to identify individual animals based on unique patterns, such as whale flukes or tiger stripes.

Natural Language Processing (NLP):

How it works: AI scans online marketplaces, social media, and e-commerce platforms to detect coded language or suspicious listings related to wildlife trafficking.

Tools:

WWF's Cyber Spotters Programme: Uses machine learning to isolate potential illegal wildlife trade listings online.

TRAFFIC's Wildlife Trade Monitoring System: Monitors online platforms for illegal wildlife trade.

Behavioral Pattern Analysis:

How it works: AI analyzes patterns in shipping data, user behavior on online platforms, and transaction histories to identify trafficking networks.

Tools:

AI-driven Risk Management Systems: Prioritize high-risk targets for law enforcement.

Automated Scanning at Ports:

How it works: AI enhances X-ray and scanning technologies at ports to detect illegal wildlife products hidden in cargo or luggage.

Tools:

AI-integrated X-ray Scanners: Automatically flag suspicious items for further inspection.

Protection

Monitoring Ecosystems:

How it works: AI-powered drones and satellite imagery monitor habitats like mangroves, coral reefs, and seagrass meadows to detect illegal activities such as logging, fishing, or habitat destruction.

Tools:

Global Forest Watch: Uses satellite data and AI to monitor deforestation.

FlyPix AI: Automates ecosystem monitoring using geospatial analysis.

Predictive Analytics:

How it works: AI predicts trafficking hotspots and vulnerable species by analyzing historical data,

environmental changes, and socio-economic factors.

Tools:

AI-driven Predictive Models: Forecast potential threats to ecosystems and species.

Real-Time Alerts:

How it works: AI systems send real-time alerts to authorities when suspicious activities are detected, enabling swift action to prevent trafficking.

Tools:

IoT-enabled Sensors: Detect changes in ecosystems and send alerts.

Community Engagement:

How it works: AI chatbots and apps educate local communities about the importance of protecting endangered species and provide tools to report illegal activities.

Tools:

Wildlife Witness App: Allows users to report wildlife trafficking incidents.

By integrating these tools and techniques, AI can significantly enhance efforts to detect and protect endangered marine flora and fauna.

Image recognition, also known as image classification, is a fascinating application of Artificial Intelligence (AI) that allows machines to identify objects, people, or patterns within digital images. Here's a detailed look at how it works step by step:

1. Data Collection

To train an image recognition system, a vast dataset of labeled images is collected. For example, if the goal is to recognize marine species, the dataset might include images of turtles, corals, fishes, etc., all labeled correctly.

Tools Used:

Online image repositories

Crowdsourced data from contributors or researchers

2. Preprocessing the Data

Images in the dataset go through preprocessing to ensure they are standardized and optimized for model training.

Techniques:

Resizing: To make all images the same dimensions.

Normalization: Scaling pixel values (e.g., between 0 and 1) for faster computation.

Augmentation: Enhancing the dataset by flipping, rotating, or cropping images to account for variations in perspective.

3. Feature Extraction

The system needs to understand what distinguishes one object from another. This is done using key "features" like edges, textures, shapes, or colors in an image.

Techniques:

- Edge Detection Algorithms: Identify boundaries (e.g., Sobel or Canny Edge Detector).
- Histogram of Oriented Gradients (HOG): Captures the shape and appearance of an object.
- In modern systems, deep learning automates this step, bypassing manual feature extraction.

4. Model Selection and Training

Deep Learning: Neural networks, particularly Convolutional Neural Networks (CNNs), are used for image recognition because of their ability to identify spatial patterns.

How CNNs Work:

Convolutional Layers: Extract patterns like edges and textures.

Pooling Layers: Reduce the spatial size of data for efficient computation.

Fully Connected Layers: Combine all features to make predictions (e.g., what species the image contains).

Models are trained using large-scale labeled datasets and optimized using algorithms like backpropagation.

5. Model Testing and Validation

A portion of the dataset is reserved for testing (unseen during training). This ensures the model generalizes well to new images.

Techniques Used:

Precision & Recall: Measure how accurately the system identifies objects.

Confusion Matrix: Highlights where the model performs well or struggles.

6. Deployment

Once tested, the model is deployed for real-world use, such as in apps, software, or embedded systems.

Applications:

Wildlife protection (e.g., identifying endangered species)

Industrial monitoring (e.g., defect detection in products)

Healthcare (e.g., diagnosing diseases from medical images)

7. Real-Time Recognition

After deployment, the system can process and recognize new images in real-time.

Techniques:

Cloud Integration: Complex computations occur in the cloud to handle large-scale tasks.

On-device Models: Lightweight models for immediate recognition on smartphones or IoT devices.

Popular Tools for Image Recognition

TensorFlow & PyTorch: Open-source frameworks for building and training neural networks.

OpenCV: A library for computer vision tasks, including image recognition.

Google Cloud Vision API: A prebuilt AI tool for detecting and classifying objects in images.

YOLO (You Only Look Once): A real-time object detection model.

Image recognition has revolutionized fields ranging from conservation to healthcare and beyond.

Key Aspects of Image Recognition

1. Convolutional Neural Networks (CNNs) – The Backbone of Image Recognition

CNNs are the gold standard for image recognition tasks. They process images similarly to how a human brain detects patterns, shapes, and textures.

- **Convolutional Layers**: These extract essential features like edges, curves, and textures.
- **Pooling Layers**: These downsample the image data, reducing computational load while keeping key information intact.
- **Fully Connected Layers**: These layers consolidate extracted features and classify them.

Popular tools: **TensorFlow, PyTorch, Keras**.

2. Object Detection & Tracking

Image recognition isn't just about identifying objects—it can also track their movement over time.

- **YOLO (You Only Look Once)**: A real-time object detection system that can analyze images and recognize multiple objects in one pass.
- **Faster R-CNN**: A model designed for rapid object identification in complex images.
- **DeepSORT**: Used for tracking moving objects across video frames.

Use cases:

- Identifying illegal wildlife trade.
- Monitoring endangered marine species in real-time.

3. Edge Detection – Identifying the Shape & Boundaries of Objects

Edge detection helps AI understand the structure of objects by identifying the boundary points.

- **Sobel Filter**: Detects gradients in an image, helping to distinguish object boundaries.
- **Canny Edge Detector**: A more advanced filter that highlights clear edges while reducing noise.

Use cases:

- Identifying fish species from underwater cameras.
- Differentiating marine flora from artificial debris in the ocean.

4. Transfer Learning – Making AI Smarter with Fewer Training Images

Instead of training a model from scratch, transfer learning enables AI to use pre-

trained models to recognize new objects faster.

- **VGGNet, ResNet, EfficientNet**: These networks have already learned to identify general image features. They can be fine-tuned to recognize species like turtles, sawfish, or corals.

Use cases:

- Training AI to recognize endangered species without needing massive amounts of image data.
- Helping conservationists categorize marine biodiversity more efficiently.

5. AI in Satellite & Drone Imagery for Environmental Monitoring

AI-enhanced satellite and drone imagery is revolutionizing conservation efforts. It allows tracking of deforestation, illegal fishing activities, and habitat loss.

- **Google Earth Engine**: Uses AI to analyze environmental changes over time.
- **Orbital Insight**: Uses geospatial AI to detect deforestation and marine ecosystem degradation.

Use cases:

- Monitoring changes in mangrove forests over time.
- Detecting illegal fishing vessels harming protected species.

Next Steps

Great! Let's dive into a hands-on implementation and explore real-world case studies of AI-powered image recognition used in conservation.

1. Implementing Image Recognition for Wildlife Protection

Implementing with AI-based image recognition using open-source tools like TensorFlow and PyTorch. Here's a basic framework:

Step 1: Gather a Dataset

Collect images of endangered marine species (e.g., turtles, sharks, seagrasses).

Use datasets from sources like Kaggle, Google Open Images, or wildlife conservation organizations.

Step 2: Preprocess Images

Normalize images to standard dimensions.

Apply image augmentation (rotation, flipping, brightness adjustments) to improve model accuracy.

Step 3: Train a CNN Model

Use a pre-trained model like ResNet, VGGNet, or EfficientNet for transfer learning.

Fine-tune the model using labeled image datasets of marine flora and fauna.

Step 4: Deploy the Model

Deploy the model using an API or integrate it into a mobile app.

Real-time classification can help conservationists track endangered species.

Example Tool: Google's TensorFlow Object Detection API—ideal for identifying wildlife in photos or videos.

2. Real-World Case Studies

AI is already making a significant impact in wildlife protection. Here are some examples:

Case Study 1: AI-Powered Anti-Poaching Surveillance (SMART Monitoring)

AI-integrated drones and thermal imaging cameras detect illegal poaching in protected marine areas.

Conservation groups like WWF and National Geographic use deep learning to identify suspicious activities.

Case Study 2: AI for Coral Reef Health Monitoring

The CoralNet project utilizes AI to analyze underwater images, identifying the health of coral reefs automatically.

Researchers can classify coral species and detect bleaching events without human intervention.

Case Study 3: Identifying Trafficked Marine Products

AI scans marketplaces and shipping databases to detect illegal trade of endangered marine species.

TRAFFIC and Wildlife Justice Commission employ machine learning algorithms to flag suspicious transactions.

Next Steps

Setting Up the Environment

Install the following libraries:

pip install tensorflow keras numpy matplotlib opencv-python

- TensorFlow/Keras: For deep learning model development.
- NumPy: For numerical operations.
- Matplotlib: For visualizing data.
- OpenCV: For image processing.

2. Loading and Preprocessing the Data

A dataset of marine species can be downloaded an open-source dataset from Kaggle or another repository.

import tensorflow as tf from tensorflow.keras.preprocessing.image import ImageDataGenerator import numpy as np import cv2 # Load dataset datagen = ImageDataGenerator(rescale=1./255, validation_split=0.2) train_data = datagen.

import tensorflow as tf

from tensorflow.keras.preprocessing.image import ImageDataGenerator

```
import numpy as np

import cv2

# Load dataset

datagen = ImageDataGenerator(rescale=1./255, validation_split=0.2)

train_data = datagen.flow_from_directory("marine_species_dataset",

                                         target_size=(128, 128),

                                         batch_size=32,

                                         subset="training")



val_data = datagen.flow_from_directory("marine_species_dataset",

                                       target_size=(128, 128),

                                       batch_size=32,

subset="validation")
```

This step: ✔ **Rescales images** to normalize pixel values. ✔ **Splits dataset** into training and validation sets.

3. Building a CNN Model

Convolutional Neural Networks (CNNs) to classify images could be used.

```
model = tf.keras.Sequential([

    tf.keras.layers.Conv2D(32, (3,3), activation='relu', input_shape=(128,128,3)),

    tf.keras.layers.MaxPooling2D(2,2),

    tf.keras.layers.Conv2D(64, (3,3), activation='relu'),

    tf.keras.layers.MaxPooling2D(2,2),

    tf.keras.layers.Flatten(),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.Dense(5, activation='softmax')  # Assuming 5 classes/species

model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])

model.summary()
```

This step: ✔ **Uses convolutional layers** to extract features. ✔ **Max pooling** reduces data complexity. ✔ **Dense layers** help classify species.

4. Training the Model

Train the CNN.

```
model.fit(train_data, validation_data=val_data, epochs=10)
```

This step:

✔ **Trains the model** to learn patterns in marine species.

✔ **Validates results** using test data.

5. Real-Time Image Recognition Using OpenCV

Now, let's test real-time recognition with an image.

```
def predict_species(image_path):
    img = cv2.imread(image_path)
    img = cv2.resize(img, (128,128))
    img = np.expand_dims(img, axis=0) / 255.0  # Normalize

    prediction = model.predict(img)
    species = np.argmax(prediction)

    species_dict = {0: "Green Turtle", 1: "Dugong", 2: "Knifetooth Sawfish", 3: "Humphead Wrasse", 4: "Vaquita"}

    return species_dict[species]

print(predict_species("test_image.jpg"))
```

This step: ✔ **Loads an image** and preprocesses it. ✔ **Classifies species** using the trained model.

Next Steps

Data Augmentation: Helps improve accuracy by exposing the model to variations, like **flipping, rotating, adjusting brightness**.

```
base_model = tf.keras.applications.ResNet50(weights='imagenet', include_top=False, input_shape=(128, 128, 3))

# Freeze initial layers

for layer in base_model.layers:

    layer.trainable = False

# Add custom classification layers

model = tf.keras.Sequential([

    base_model,

    tf.keras.layers.Flatten(),

    tf.keras.layers.Dense(256, activation='relu'),

    tf.keras.layers.Dropout(0.3),

    tf.keras.layers.Dense(5, activation='softmax')  # 5 species classes

])
```

Benefits: ✔ Uses knowledge from a pre-trained model (**ResNet**) to improve accuracy.
✔ Works well with small datasets.

2. AI + IoT for Real-Time Wildlife

Acoustic Sensors → AI can analyze underwater sounds to detect marine mammal presence (e.g., whales, dolphins) and alert conservationists.

Example – AI + IoT Smart Camera System:

```
import cv2

# Load AI model trained to detect marine species
model = tf.keras.models.load_model("marine_species_model.h5")

# Access live camera feed (IoT device)
video = cv2.VideoCapture("ocean_live_feed.mp4")

while True:
    ret, frame = video.read()
    if not ret:
        break

    img = cv2.resize(frame, (128,128)) / 255.0
```

```
    img = np.expand_dims(img, axis=0)
    prediction = model.predict(img)

    species_dict = {0: "Green Turtle", 1: "Dugong", 2: "Sawfish", 3: "Humphead Wrasse", 4: "Vaquita"}
    detected_species = species_dict[np.argmax(prediction)]

    print(f"Detected: {detected_species}")

video.release()
cv2.destroyAllWindows()


model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

Impact: ✔ Enables **real-time** endangered species identification using AI-powered cameras. ✔ Helps **monitor marine habitats** to track ecosystem health.

The next steps in fine-tuning the model, integrating AI with IoT devices, and applying AI-powered image recognition for conservation efforts.

1. Fine-Tuning the Model for Better Accuracy

Even though we've built a basic image recognition model, it can be fine-tuned to improve performance and accuracy.

Key Techniques for Fine-Tuning:

Transfer Learning: Instead of training from scratch, we use a pre-trained model (like ResNet, EfficientNet) and modify its final layers.

Data Augmentation: Helps improve accuracy by exposing the model to variations, like flipping, rotating, adjusting brightness.

Hyperparameter Tuning: Adjusting parameters like the learning rate, batch size, and number of layers to optimize training.

Example – Applying Transfer Learning:

```
base_model = tf.keras.applications.ResNet50(weights='imagenet', include_top=False, input_shape=(128, 128, 3))

# Freeze initial layers

for layer in base_model.layers:

    layer.trainable = False

# Add custom classification layers

model = tf.keras.Sequential([

    base_model,

    tf.keras.layers.Flatten(),

    tf.keras.layers.Dense(256, activation='relu'),

    tf.keras.layers.Dropout(0.3),

    tf.keras.layers.Dense(5, activation='softmax')  # 5 species classes

])



model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

Benefits: ✔ Uses knowledge from a pre-trained model (ResNet) to improve accuracy.
✔ Works well with small datasets.

2. AI + IoT for Real-Time Wildlife Monitoring

AI can be combined with IoT devices (like smart cameras, underwater drones, sensors) to track endangered marine species and ecosystem health in real-time.

IoT + AI Applications:

Underwater Smart Cameras → AI-powered cameras monitor species like turtles, corals, or sharks and detect illegal fishing activities.

Drones → AI-integrated drones scan coastal regions to identify mangrove deforestation and wildlife poaching.

Acoustic Sensors → AI can analyze underwater sounds to detect marine mammal presence (e.g., whales, dolphins) and alert conservationists.

Example – AI + IoT Smart Camera System:

```
import cv2

# Load AI model trained to detect marine species

model = tf.keras.models.load_model("marine_species_model.h5")

# Access live camera feed (IoT device)

video = cv2.VideoCapture("ocean_live_feed.mp4")

while True:

    ret, frame = video.read()

    if not ret:

        break

    img = cv2.resize(frame, (128,128)) / 255.0

    img = np.expand_dims(img, axis=0)

    prediction = model.predict(img)

        species_dict = {0: "Green Turtle", 1: "Dugong", 2: "Sawfish", 3: "Humphead Wrasse", 4: "Vaquita"}

    detected_species = species_dict[np.argmax(prediction)]

        print(f"Detected: {detected_species}")

video.release()

cv2.destroyAllWindows()
```

Impact: ✔ Enables real-time endangered species identification using AI-powered cameras. ✔ Helps monitor marine habitats to track ecosystem health.

3. AI for Conservation Efforts – Case Studies

AI is already transforming wildlife protection efforts worldwide. Some real-world conservation projects:

Case Study 1: AI-Powered Anti-Poaching Systems

Organizations like WWF and Wildlife Protection Units use AI-enhanced drones to detect illegal fishing boats and poachers in marine protected areas.

AI predicts poaching hotspots, allowing authorities to take preventative action.

Case Study 2: AI for Coral Reef Monitoring

CoralNet AI identifies coral species and tracks bleaching patterns using underwater cameras.

Researchers use AI-powered data insights to restore reefs affected by climate change.

Case Study 3: AI Detecting Illegal Marine Trade

TRAFFIC and Wildlife Justice Commission deploy AI models that scan social media & e-commerce platforms to detect illegal wildlife trade (e.g., endangered marine species being sold online).

AI flags suspicious transactions, helping law enforcement intercept illegal trafficking.

Next Steps:

1. Build a more advanced AI model with real-time underwater detection
2. Integrate AI with drones and IoT devices for marine monitoring
3. Explore global conservation projects powered by AI

Build a More Advanced AI Model for Real-Time Underwater Detection

Imagine an AI model that can analyze **live underwater footage** and automatically detect endangered marine species. Here's how we can refine it:
✔ **Use YOLO (You Only Look Once) for real-time object detection** to identify marine life efficiently.
✔ **Train the model on underwater datasets** (including coral reefs, turtles, and sharks) using AI techniques like **data augmentation** to handle murky waters.
✔ **Deploy the model on an edge device**, such as Raspberry Pi, connected to an underwater **IoT camera**, allowing conservation teams to monitor marine biodiversity automatically.

2 Integrate AI with Drones & IoT for Marine Monitoring

Drones and IoT sensors are game-changers in tracking illegal fishing, marine habitat changes, and endangered species. Here's how AI can help:
✔ **AI-powered drones** with thermal imaging can scan for illegal activities like **mangrove deforestation** or **marine poaching** in protected areas.
✔ **Acoustic AI sensors** placed in oceans can detect **dolphin & whale sounds** to prevent unintended harm from shipping routes.
✔ **Smart IoT buoys** powered by AI can

monitor pollution levels and **alert marine conservation groups** in real time.

Explore how AI-powered **IoT devices** can help in tracking marine life

Explore Global Conservation Projects Using AI

AI is already **revolutionizing conservation efforts** worldwide! Some inspiring projects:
✔ **CoralNet AI** – Uses **deep learning** to scan coral reefs and assess bleaching risks due to climate change.
✔ **Global Fishing Watch** – Monitors **illegal fishing** using satellite + AI to detect vessels violating conservation laws.
✔ **Wildlife Crime AI** – Analyzes **social media & marketplaces** to track the illegal trade of endangered marine species.

Conclusion

Artificial Intelligence has the potential to transform conservation efforts for endangered marine flora and fauna. By combining detection methods (image recognition, predictive analytics) with protection strategies (IoT monitoring, automated alerts), AI provides a robust framework to address trafficking and habitat loss. Future research and collaboration between technologists and conservationists can further refine these tools for global impact.

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